FLORISTIC SURPRISES IN NORTH AMERICA NORTH OF MEXICO[1]

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Abstract

Contrary to recurring perceptions that the flora of North America north of Mexico has been fully explored and cataloged, the rate of ongoing discoveries has remained remarkably constant for much of the last century and shows no evidence of tapering off. This is particularly evident in western and southeastern North America, where dramatic new species and occasional monotypic genera are still coming to light, even along highways and near major cities. Furthermore, the same level of ongoing discovery also characterizes other aspects of floristic information, including the distribution of rare species and the occurrence of invasive pest plants. The majority of ongoing discoveries are dependent on individuals and organizations operating outside of academia, with declining opportunities for formal training in floristics or access to scientific expertise when complex situations are encountered. This situation is connected to the perception of floristics as rote data compilation, when it is in fact better understood in the context of a massive attempt to model biodiversity, resulting in an intricate suite of nested hypotheses that are constantly being tested and modified. The incompleteness of our floristic knowledge takes on critical significance in an era when decisions are being made that will irrevocably determine the fate of our national floristic heritage. The cost of this ignorance can cut multiple ways, increasing the risk of misplaced mitigation efforts as well as avoidable loss of irreplaceable biodiversity. Although the magnitude of the task is daunting, significant advances are achievable in a collaborative framework, which would yield a vastly improved floristic knowledge base for informed decision-making.

Key words: biodiversity, floristics, North America, vascular plant flora.

Underlying much of our current land-use management planning, legislation, funding allocations, and hiring decisions is the assumption that the flora of North America north of Mexico (for brevity's sake, hereafter referred to simply as "North America") has been fully explored, cataloged, and mapped, at least to the extent that is needed for informed decision-making. Or, to the extent that exceptions are allowed, it is assumed that such knowledge accumulates in the form of static data sets, descriptive rather than truly scientific in nature, and further that the existing academic infrastructure is adequately addressing the gaps in our floristic knowledge. This paper sets out to challenge these assumptions, as well as the equally common perception that floristic surveys inevitably represent a threat to private landowners. The first half of the paper provides testimony to the wealth and diversity of ongoing floristic surprises in North America, whereas the second half addresses the factors that influence these discoveries and the resultant implications.

The majority of statistics and examples that form the basis of this paper are derived from the author's personal expertise and vascular plant focus. The resultant western North American bias should not, however, obscure the fact that this region is a rich source of ongoing novelties. An effort has nevertheless been made to include examples from other geographic areas and representing other groups traditionally studied by botanists: bryophytes, algae, fungi, and lichens. The proportional representation of examples should not be taken as an accurate reflection of actual discoveries among geographic areas and plant groups, or of their significance to science or land-management issues.

Assumption 1: The Fully Cataloged Flora

A. Historical Perceptions

The perception that the vascular plant flora of North America has been fully explored and cataloged has a surprisingly long history, as analyzed from our current state of knowledge. As early as 1858, Thomas Bridges, an Englishman collecting in California, wrote the following to Sir William J. Hooker (quoted in Jepson, 1933):

> "I can scarcely describe to you how pleasing and gratifying it has been to me to learn that in my collections you have found some new and rare plants—I was partially under the impression that from the labours of Douglas, Hartweg, Jeffrey, Lobb and other travelers

[1] Excerpts from the October 1998 presentation on which this paper is based have been subsequently highlighted in several media publications, notably *U.S. News and World Report* (Tangley, 1998) and *Science News* (Milius, 1999).

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from Europe with the many United States Exploring Expeditions that little or nothing remained to be discovered and only gleanings were left to those of us of the present day."

As it happens, the "gleanings" left by Bridges's predecessors comprised the majority of California's flora as currently known. In fact, the number of known species increased by one-fourth during the subsequent two decades under the auspices of the California Geological Survey, primarily due to the efforts of William H. Brewer and Henry Nicholas Bolander. The two-part botanical report of the California Geological Survey (Brewer et al., 1876; Watson, 1880), which represented the first comprehensive flora of California, included full entries for approximately 3450 vascular plant taxa. This contrasts both with the initial estimate of 2000 (as noted in Whitney's introduction to the first volume) and the latest tally of 7036 vascular plant taxa recognized as occurring outside of cultivation in California (Hickman, 1993). Not only were there only half the number of taxa known in 1880 as in 1993, but there is by no means a strict one-to-one correspondence within the apparent overlap, primarily due to misapplied names and non-persisting introductions.

As it happens, Bolander was himself guilty of seriously underestimating what still lay waiting to be found, when he challenged Alphonso Wood's claim of collecting 1490 species of flowering plants on a journey from San Diego up the coast and through northern California in 1866. In an address to the California Academy of Natural Sciences, "Professor Bolander considered it probable that there were not over 500 species of flowering plants actually existing in that part of California" (Leviton & Aldrich, 1997: 87). On the contrary, well over 4000 taxa of vascular plants are now known to occur in the biogeographic subdivisions of California that Wood traversed (as calculated from Hickman [1993] by R. L. Moe, pers. comm. 1998), though how many of these Wood actually encountered is admittedly another matter.

Bolander's attitude was in full sway several decades later, when Katharine Brandegee accused Edward Lee Greene of conflating California's flora, with the statement, "It is safe to say that not more than one in ten of [Greene's] species is tenable, and probably one in fifteen or twenty would be nearer the mark" (Brandegee, 1893: 64). It turns out that Brandegee was actually the one who was way off the mark, in that a respectable 70% of Greene's taxa, at least those described while he was residing in California, have stood the test of time (McVaugh, 1983).

A marvelous anecdote relayed by Heller (1908: 12–13) from one of his correspondents shows just how well ensconced was the general belief that the North American flora had been fully cataloged by the end of the 19th century:

"[M]y first botanical work was done in California, where my teacher was looked upon by me as the complete essence of knowledge, and everything she said was right—and such is often the case when one is fourteen years old . . . . At the time I used to range over territory [in the mountains near San Diego] which probably was not searched over botanically or ornithologically before nor since . . .. Sometimes as a result I would return with 30 or 40 plants, and after vain attempts to name them in my botany (Rattan's Popular Flora) would take them to the teacher. The usual words which took place were about as follows on the teacher's part: 'Can't you find these in the botany?' 'No.' Study of the specimens and consulting the botany followed on the teacher's part, with the usual ending by her saying: 'They are not given in the botany. They are not good for anything on that account. Throw them away.' "

As a final example in the botanical lore, one of Brandegee's supporters, Marcus E. Jones, is said to have commented that "he felt sorry for all future generations of botanists because he [Jones] had named all the western American taxa, and there would be nothing left for them to do" (S. Welsh, pers. comm. 1998). To the contrary, the rate of discovery of rare plants in Jones's home base of Utah remains high, with a significant peak in the 1980s (Stone, 1998; Fig. 1).

In essence, the inclination to believe that the era of floristic exploration in North America is over apparently has an inherent persistency to the point of becoming a psychological phenomenon worth investigating in its own right. In the words of Stan Welsh (pers. comm. 1998), "Each major publication on western plants has left the impression that all of the work has been done, that nothing remains to be discovered, that everything worth naming has been named." The perceptions of the 19th century have accordingly become the dogma of the 20th century, in which the common understanding is that the flora of North America has, with the rare exception, been fully explored, cataloged, and mapped (Reveal, 1991). At its worst, the attitude developed that anyone describing new species of plants from North America was indulging in species conflation for the sake of ego gratification, rather than practicing valid science.

Against this tide, there have admittedly been some voices to the contrary. In his introduction to the second volume of the botanical report of the

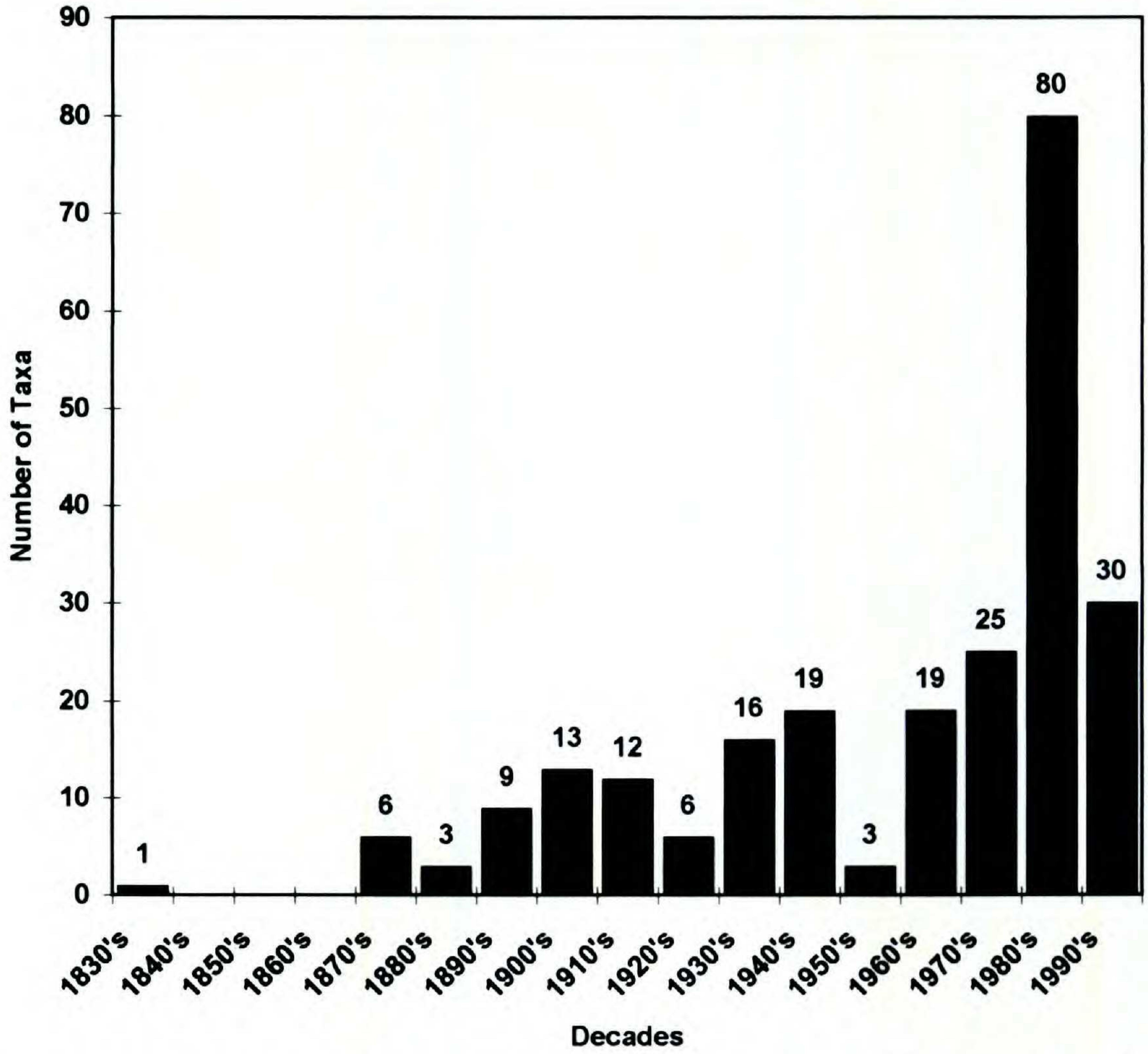

Figure 1. History of rare plant description in Utah (figure and caption prepared by R. D. Stone). Bars represent the number of rare vascular plant taxa (species, subspecies, and varieties) in Utah that were formally described within each 10-year period. Rare plants (N = 242) are defined as those taxa "with known or suspected range-wide viability concern" (Stone, 1998). The data show that most rare plants in Utah are recently described. This is understandable for two reasons: (a) plants are often considered rare when they are first described but tend to be removed from rare lists as they become better known; and (b) after more than a century of plant exploration and discovery in Utah, the plants now being described tend to be "the rarest of the rare."

Geological Survey of California, Watson (1880) indicated, "There still remains ample opportunity for good botanical work at almost any locality among the mountains, hills, and valleys of the State, to which it is hoped that these volumes may prove both an incentive and an aid." And, in a summation lecture of a symposium on the Broadening Basis of Classification, Lincoln Constance (1964) noted, "Many otherwise informed persons assume that the exploratory phase of botany is essentially complete; this assumption is, of course, entirely erroneous."

B. STATISTICAL CHALLENGES

(1) Shevock & Taylor (1987)

Possibly the first statistical challenge to the common perception was that of Shevock and Taylor in 1987, provocatively titled "Plant exploration in California: The frontier is still here." In it, the authors tallied 219 vascular plants described from California for the two decades from 1968 to 1986, an average of 11 taxa per year. Taylor (pers. comm. 1998) has continued the analysis, demonstrating that the rate of discovery remains constant (Fig. 2). He further extrapolates that, if the rate of discovery begins to taper off right now and follows the curve displayed by more fully cataloged parts of North America (e.g., the northeastern United States), a *minimum* of 300 or more undescribed vascular plant taxa are still waiting in the wings in California alone (Fig. 3).

(2) Hartman & Nelson (1998)

Furthermore, although California clearly leads the pack, a recent publication by Hartman and Nelson (1998) demonstrates the pervasiveness of ongoing floristic discovery throughout North America. For the two decades from 1975 through 1994, a total of 1197 vascular plant taxa were described as

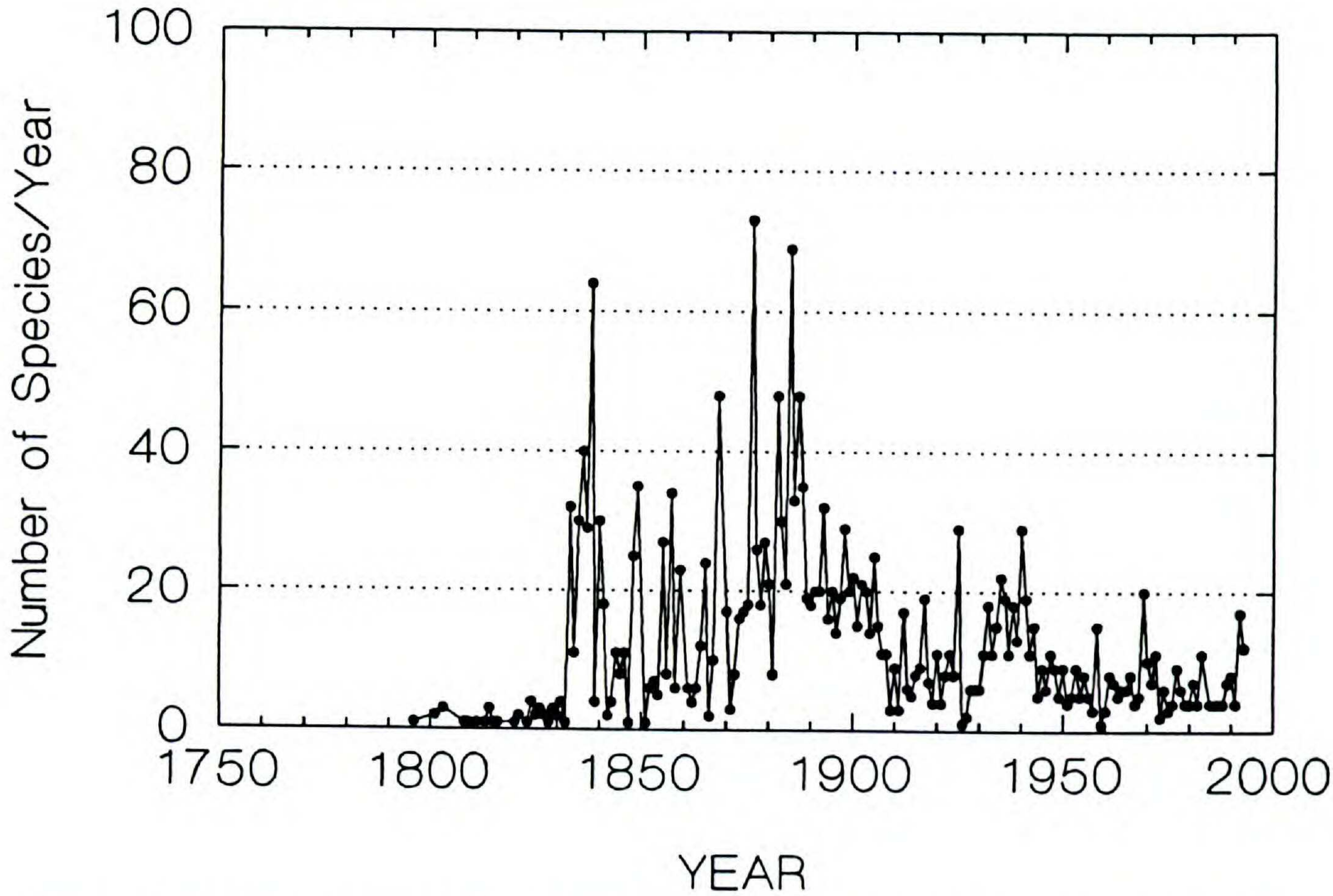

Figure 2. Yearly description rate of endemic species of plants in California and/or the California Floristic Province (prepared by D. W. Taylor, unpublished data).

new to science, ranging from monotypic genera to formae and nothotaxa (collectively referred to as "novelties"). The 603 full species comprise 3.21% of the 18,781 currently estimated to occur in North America (1998 estimate provided by *Flora of North America North of Mexico*). The overwhelming majority are from the western and southeastern United States, but essentially all states and provinces contributed to the total (including a forma from Rhode Island, *Lindera benzoin* f. *rubra* R. L. Champlin). Most are angiosperms, but 78 pteridophytes and 6 gymnosperms are represented.

Other statistics compiled by Hartman and Nelson included:

Number of holotypes by political unit (excluding formae and nothotaxa). Top 10 = California (217), Utah (183), Texas (70), Nevada (63), Arizona (57), Oregon (42), New Mexico (41), Florida (38), Idaho (33), and Wyoming (32).

Families with the greatest number of novelties (excluding formae and nothotaxa). Top 10 = Asteraceae (186), Brassicaceae (91), Fabaceae (84), Scrophulariaceae (46), Polygonaceae (46), Poaceae (44), Cactaceae (36), Liliaceae (30), Apiaceae (27), and Lamiaceae (26).

Authors of novelties. Top 10 = S. L. Welsh (118), R. C. Rollins (62), J. L. Reveal (45), R. C. Barneby (32), G. L. Nesom (26), N. H. Holmgren (25), W. H. Wagner (24), B. L. Turner (23), S. Goodrich (19), and B. Ertter (18).

Taking into consideration that not all published novelties are subsequently accepted as worthy of taxonomic recognition, Hartman and Nelson accordingly calculated the acceptance rate in a variety of taxonomic works, ranging from 63% to 98%, with somewhere around 90% apparently being the norm. This may in fact be an underestimation, if a recent study by Windham and Beilstein (1998a, b) is any indication, ironically involving the two leading authors of novelties. Lest anyone assume that Welsh's impressive total (nearly double that of Rollins's) results from a bad case of species conflation, Windham and Beilstein give strong evidence that Welsh erred on the conservative side in at least one instance. Not only did the elegant convergence of micromorphological, molecular, and other evidence show that Welsh mistakenly lumped some of Rollins's species of *Draba* (Brassicaceae), but furthermore indicated that Rollins himself had confused taxa that were morphologically convergent but only distantly related.

Parallel to Taylor's analysis, Hartman and Nelson showed that the rate of publication of taxonomic

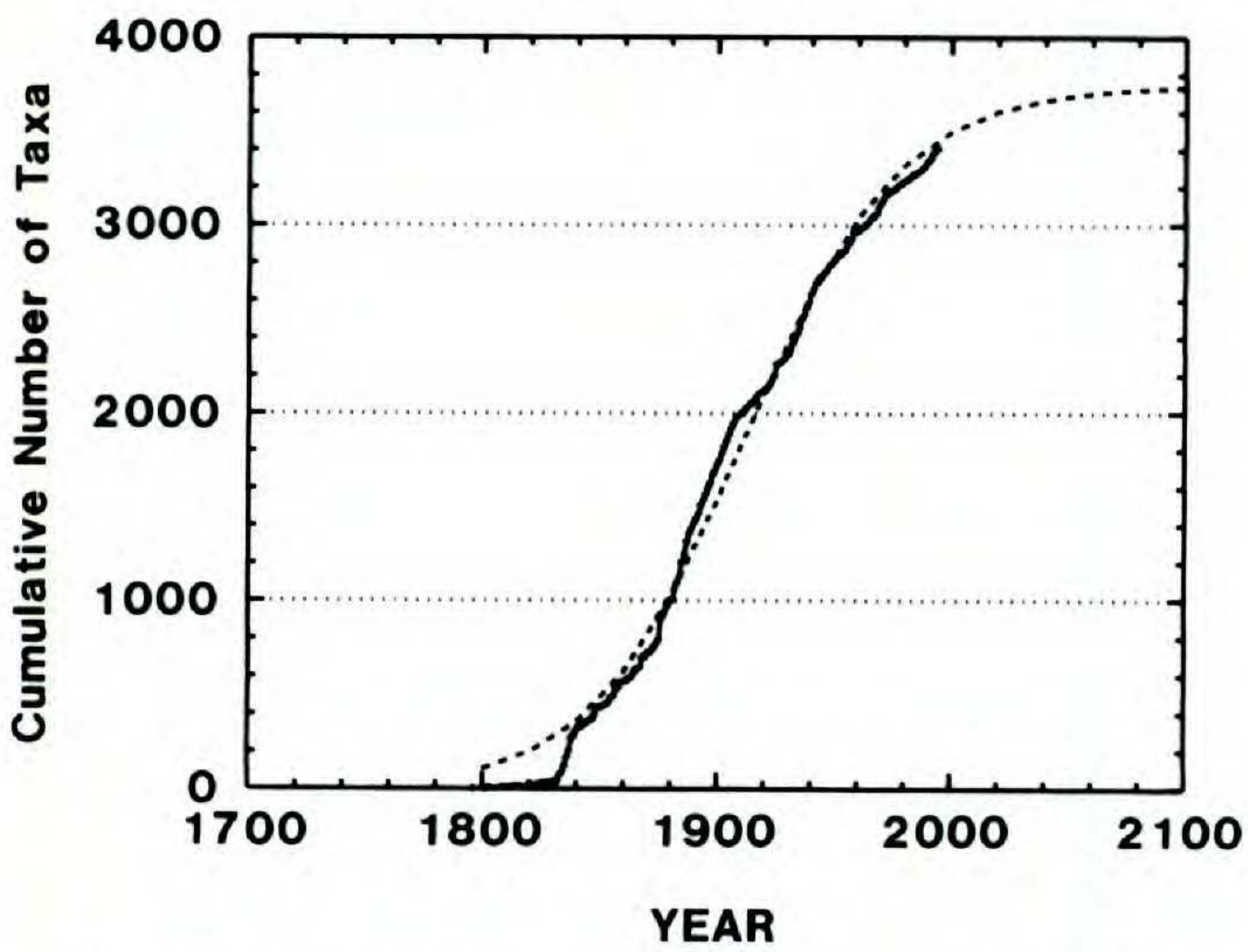

Figure 3. Curve depicting the historical trend in discovery of endemic plants of the California region and an approximative extrapolation of a possible future trend (fig. and caption prepared by D. W. Taylor). The solid line shows the rate of accumulation of published names through publication of *The Jepson Manual* (Hickman, 1993). The data set includes those endemic taxa as recognized in Hickman (1993) or Skinner and Pavlick (1994), plus some 18 taxa found in the Oregon portion of the California Floristic Province, 120 taxa found in the Baja California portion, and 2 taxa found in the Sierra Nevada portion of Washoe County, Nevada. The fitted curve (dashed line) was obtained by iterative nonlinear estimation modeling (employing Wilkinson, 1990) with a cumulative logistic assumption of curve shape. The assumed diminishing-return curve shape was selected based on the observed trends in decline of novelties for the vascular flora of New England and North American conifers (Taylor, unpublished data). The best-fit solution predicts a leveling-off in about 90 years, after an additional 298 taxa have been described. The model shown here is conservative, forcing a decline to equilibrium coincident to publication of *The Jepson Manual* in 1993. The observed trend shows no direct evidence of such a decline, however, in that an additional 26 new taxa have been described between 1994 and 1998 (D. Taylor, unpublished data).

novelties has remained relatively constant since 1955, averaging nearly 60 per year. They predicted, however, that the rate of publication of novelties will diminish once *Flora of North America North of Mexico* (FNA) is completed. It is accordingly worth noting that Taylor's statistics do not show a comparable drop following the appearance of *The Jepson Manual* (Hickman, 1993); if anything, the appearance of an up-to-date flora has spurred essential fieldwork and increased the likelihood of recognizing a novelty as such. There is at least one example already that the appearance of a generic treatment in FNA is independent of ongoing discoveries: Warren H. and Florence Wagner (1994; pers. comm. 1998) report that they have already accumulated six new species of *Botrychium* beyond the 30 included in their treatment for FNA (Wagner & Wagner, 1993).

Although it is impossible to know exactly how much remains unknown, a calculation based on Taylor's method of extrapolation has at least some conceptual validity. If Taylor's extrapolation of 300+ still-to-be-discovered vascular plant novelties in California is accurate, and if the 1:6 ratio of California-to-North America novelties remains constant, then at least 1800 more novelties can be expected for North America. If half are full-fledged species (as in Hartman and Nelson's analysis), then nearly 5% of the North American vascular plant flora is still undescribed!

(3) Non-vascular plants and fungi

Comparable statistics have not previously been published for non-vascular plants and fungi, but Marshall Crosby and Raymond Stotler have compiled the raw numbers on mosses and liverworts, respectively, kindly making them available for this paper. From 1975 to 1998, a total of 63 mosses were described from North America, including 42 full species (M. Crosby, pers. comm. 1998). This represents 3.17% of the 1323 species estimated for FNA, almost the same percentage as for vascular plants (3.21%). Liverworts tell a similar story, with 19 novelties described in the last 20 years, representing 3.44% of the current tally of 553 (R. Stotler, pers. comm. 1998).

Statistics generated from the *Index Nominum Algarum*, maintained by Paul Silva and Richard Moe (pers. comm. 1999), indicate that at least 63 marine macroalgae have been described from the North American coastline since 1980, with an incomplete cataloging of pre-1986 publications. This clearly indicates that algae are also still being actively discovered and identified, perhaps at even higher percentages than for vascular plants. Comparable summaries have not been generated for lichens or fungi, which in general lag behind vascular plants in terms of systematic research.

[*Note.* Although it is now well established that "plants" are represented by at least three distinct lineages (green, red, and brown), and that fungi are more closely related to animals than to green plants (e.g., the topic of a keynote symposium on "Phylogeny of Life" at the XVI International Botanical Congress), there is no evidence that these groups are being evicted from herbaria or the research realm of botanists. Their inclusion in this paper is furthermore justified by the burgeoning move to treat bryophytes and lichens, and potentially fungi and algae, under the same conservation umbrella as currently exists for vascular plants, with the issues addressed by this paper of relevance to all.]

C. EXAMPLES OF "NEW TO SCIENCE" DISCOVERIES

Although the statistics cited above are impressive in their own right, it is not evident to what extent strikingly new discoveries are represented, as compared to cryptically distinct variants of marginal significance. To address this question, a selection of the most dramatic of the newly discovered and/or described taxa are presented here, drawn from among the 1197 novelties tallied by Hartman and Nelson and numerous others published since 1994. Choosing among the wealth of riches was one of the more challenging parts of preparing this paper, with new examples constantly coming to the fore. The resultant choices are organized among the following categories:

(1) Monotypic genera

Five species covered by Hartman and Nelson were distinctive enough to be described as new monotypic genera: *Apacheria chiricahuensis* C. T. Mason (Crossosomataceae), *Cochisea robbinsorum* W. H. Earle (Cactaceae) (subsequently included within *Coryphantha* by Benson [1982]), *Dedeckera eurekensis* Reveal & J. T. Howell (Polygonaceae), *Shoshonea pulvinata* Evert & Constance (Apiaceae), and *Yermo xanthocephalus* Dorn (Asteraceae). *Apacheria* and *Cochisea* are from Arizona, *Shoshonea* and *Yermo* are from Wyoming, and *Dedeckera* is from California. *Apacheria,* found in the Chiricahua National Monument in 1973, became the second genus assigned to the family Crossosomataceae (Mason, 1975). *Yermo,* whose closest probable relatives grow in deciduous forests in eastern North America, is known from a single remote population located along a proposed pipeline route in the Wyoming desert (Dorn, 1991). *Shoshonea,* discovered by retired schoolteacher and rock-gardener Erwin Evert in 1979, has more recently been found to occur within two miles of downtown Cody, Wyoming (Evert & Constance, 1982; R. Hartman, pers. comm. 1998). The distinctive summer-blooming shrub *Dedeckera* was discovered by conservation activist Mary DeDecker (Reveal & Howell, 1976; Nilsson, 1994), with one population now known within walking distance of a scientific research station on the outskirts of Bishop, California.

Subsequent to Hartman and Nelson's publication, two more monotypic genera of vascular plants have been described, by coincidence both Brassicaceae from California. The first was *Sibaropsis hammittii* S. Boyd & T. S. Ross, with three separate occurrences encountered in the course of doing an environmental impact survey in relatively well-botanized and well-traveled portions of southern California (Boyd & Ross, 1997). The second was also discovered by a consultant in an area proposed for development, within earshot of Interstate Highway 5 in the San Joaquin Valley. Originally suspected of being yet one more introduced European annual, it was determined instead to represent a unique new species and was accordingly described as *Twisselmannia californica* Al-Shehbaz (Al-Shehbaz, 1999).

Looking beyond vascular plants, newly discovered species distinctive enough to be described as new genera are particularly common among algae. Of the 63 macroalgae cited above, eight were distinctive enough to be described as new genera: *Binghamiopsis caespitosa* I. K. Lee, J. A. West & Hommers from California; *Boreothamnion villosum* M. J. Wynne and *Orculifilum denticulatum* S. C. Lindstr. from Alaska; *Calliclavula trifurcata* C. W. Schneid. and *Nwynea grandispora* Searles from North Carolina; *Chlorojackia pachyclados* R. Nielsen & J. A. Correa from Nova Scotia; *Rhododraparnaldia oregonica* Sheath, Whittick & K. M. Cole from Oregon; and *Verosphacela ebrachia* E. C. Henry from Florida.

Among bryophytes, *Ozobryum ogalalense* G. L. S. Merrill (Pottiaceae) was also recently discovered and described as a monotypic genus (Merrill, 1992). Although it was subsequently transferred to *Molendoa* (Zander, 1993), its distinctiveness as a species remains noteworthy. The new moss is furthermore remarkable in making its appearance in the Great Plains, a region otherwise relatively depauperate in both mosses and new discoveries in general.

(2) Charismatic megaflora

The award for most publicity for a recent discovery goes to the Shasta snow-wreath, *Neviusia cliftonii* Shevock, Ertter & D. W. Taylor (Rosaceae), whose serendipitous discovery in 1992 in northern California made both *The New York Times* (2 February 1993) and the *Frankfurter Allgemeine* (30 December 1992) based on two aspects of particular significance (Shevock et al., 1992). First, the Shasta snow-wreath was the second species in a genus that had previously been known as a single rare species in the southern Appalachians, over a thousand miles away. This disjunct distribution, indicative of a Tertiary relict, was, however, less puzzling than the second aspect: namely, that this never-before-collected shrub was locally co-dominant (with poison-oak) along a well-traveled highway, 25 miles northeast of Redding, California. Once a focused search was undertaken, several additional populations were readily located, one adjacent to a developed campground. As a further anomaly, the currently known range lies largely within one of the few areas (Redding quadrangle) whose vegetation types were completely mapped and published (Weislander et al., 1939); nevertheless, *Neviusia* was not among the abundant vouchers.

As an eastern example of "charismatic megaflora," a 5–7-m-tall rosaceous shrub or small tree, discovered in Arkansas in 1970 and initially identified as either a *Crataegus* or an *Aronia*, was subsequently described as *Mespilus canescens* Phipps (Phipps, 1990). As such, it was a surprising addition to a previously monotypic genus known only from Europe, the medlar *Mespilus germanica* L. Subsequent isozyme studies supported the inclusion of the new species within *Mespilus* (Phipps et al., 1991). Described as being "of exceptional beauty," only 25 individuals are known from a single 22-acre grove.

Another contender for most charismatic recent discovery from eastern North America is the Kentucky lady's slipper, *Cypripedium kentuckiense* C. F. Reed (Orchidaceae), among the tallest and showiest species in a genus of showy orchids. Although currently known from several southeastern states, it was not described until 1981, long after the author had first encountered it cultivated in a garden (Reed, 1981). The most recently discovered population, in coastal Virginia in 1995, is only 150 km as the crow flies from the center of Washington, D.C. (Weldy et al., 1996).

(3) Botanical "hot spots"

A jackpot of undescribed species is occasionally encountered in areas of complex geology and rugged terrain, which set the stage for an often bewildering expression of island biogeography in a continental setting. In such areas, an unusual substrate or isolated mountaintop has the potential of harboring a unique suite of endemic plants, and the first botanist to reach the site can reap a bonanza of floristic surprises.

As it happens, my own career as a professional taxonomist began when I had the good fortune of participating in the discovery of one such botanical treasure trove while still an undergraduate, thanks to a newly built gravel road in the early 1970s that made Leslie Gulch in southeastern Oregon a two-hour drive by passenger car from Boise, Idaho. The unique ash-flow tuffs of Leslie Gulch have thus far yielded a total of five plant taxa new to science: *Senecio ertterae* T. M. Barkley, *Mentzelia packardiae* Glad, *Ivesia rhypara* Ertter & Reveal, *Artemisia packardiae* J. W. Grimes & Ertter, and *Phacelia lutea* var. *mackenziorum* J. W. Grimes & P. L. Packard (Grimes, 1984). Some of these species are so distinctive that their relationships remain unclear, whereas variants of several other species might prove to be taxonomically distinct upon further study. In addition, Leslie Gulch turns out to be the "mother lode" for several other species that had been known previously from only a handful of populations: *Trifolium owyheense* Gilkey, *Astragalus sterilis* Barneby, and *Eriogonum novonudum* M. Peck.

Alas, Leslie Gulch is now overshadowed by the latest "hot spot," the Ketona Glades in Bibb County, Alabama. In 1992, a group of environmental consultants undertaking a rare plant survey by canoe on the Little Cataba River came upon a calcareous glade community harboring at least seven undescribed taxa: *Spigelia gentianoides* Chapman ex A. DC. var. *alabamensis* K. Gould, *Onosmodium* sp. nov., *Erigeron strigosus* var. nov., *Dalea* sp. nov., *Castilleja* sp. nov., *Liatris* sp. nov., and *Silphium* sp. nov. In addition, several state records for Alabama were present, most with some level of formal rarity status, along with a new county record for the federally endangered *Xyris tennesseensis* Kral (Allison, 1994; Gould, 1996).

The rugged southern Sierra Nevada in California also continues to be a rich source of novelties, with three new taxa discovered in a single day on a remote marble ridge in 1996: *Heterotheca monarchensis* D. York, Semple & Shevock, *Gilia yorkii* Shevock & A. G. Day, and a still-undescribed *Eriogonum*. The ridge also harbors the only known California populations of three mosses (J. R. Shevock, pers. comm. 1998).

(4) In our backyards

Although the majority of new discoveries are encountered in relatively remote sites, a surprising number appear around significant population centers, even those with major herbaria and a long tradition of botanical exploration. Among the more dramatic of these "in our backyards" examples are the following:

- Morefield's leather-flower, *Clematis morefieldii* Kral (Ranunculaceae), was discovered in 1982 by a budding botanist who practiced by collecting specimens around his neighborhood inside the city limits of Huntsville, Alabama (Kral, 1987). Now federally listed as Endangered, the species is still only known in and near residential areas in the Huntsville area. Morefield himself, inspired by this early experience, went on to become botanist for the Nevada Natural Heritage Program.

- Not far from Las Vegas, Nevada, in the course of a floristic survey of Red Rock Canyon National Conservation Area, *Ionactis caelestis* P. J. Leary & G. L. Nesom (Asteraceae) was discovered in 1990. The highly localized population, within sight of the Las Vegas casinos, occurs on an edaphic island of sandstone surrounded by limestone. The species is distinctive enough that it might justifiably be treated as a monotypic genus (Nesom & Leary, 1992).
- Approximately 25 miles west of downtown Los Angeles, California, a few miles north of the trendy community of Malibu in the Santa Monica Mountains, *Baccharis malibuensis* R. M. Beauch. & Henr. (Asteraceae) was discovered in 1988 (Beauchamp & Henrickson, 1996). Beauchamp had earlier described another *Baccharis*, *B. vanessae* R. M. Beauch., from the midst of housing developments in central San Diego County (Beauchamp, 1980).
- Only about six miles from one of the main herbaria in Utah, on cliffs behind some summer cabins, *Viola franksmithii* N. H. Holmgren (Violaceae) was discovered in 1989 by a "modern-day naturalist" who was monitoring other rare plants known to occur in Logan Canyon (Holmgren, 1992). Disagreement exists as to taxonomic placement of this distinctive species (H. J. Ballard, pers. comm. 1998).
- A short distance outside of Yosemite National Park, among the most-visited parks in the United States, the showy-flowered *Erythronium taylori* Shevock & G. A. Allen (Liliaceae) was discovered in 1996, bringing to three the number of extremely local endemic *Erythronium* in the lower Sierra Nevada (Shevock & Allen, 1998). In addition to being the only New World species of the genus with scented flowers, *E. taylori* is intriguing in being a candidate for the *Erythronium* once reported to occur in Yosemite Valley (Brandegee, 1891), where no representatives of the genus are currently known (D. W. Taylor, pers. comm. 1998).
- In spite of growing less than 10 miles from downtown San Francisco, California, in an extensively botanized county with a recently updated flora (Howell, 1970), *Calochortus tiburonensis* A. J. Hill (Liliaceae) was not discovered until 1972. The species is so distinctive that "its existence challenges the currently accepted infrageneric classification" (Hill, 1973: 104). The protologue furthermore noted, "That a previously uncollected new species . . . was discovered in such a botanically well known area suggests the need for a very careful look at any areas that are threatened by development or other disturbance, especially near expanding population centers. Had this species not been noticed soon, it might very well have become extinct without ever having been recorded."
- Nestled among the Lick Observatory complex on Mount Hamilton, within easy reach of the University of California at Berkeley, the California Academy of Sciences, and Stanford University, *Lomatium observatorium* Constance & Ertter (Apiaceae) was not described until 1996, too late to be included in Hartman and Nelson's synopsis. Its location on Mount Hamilton was brought to the attention of Lincoln Constance, the expert on *Lomatium*, by a wildflower photographer, Nigel Hancock (Constance & Ertter, 1996).

(5) Species-rich genera

Lomatium, with 10 novelties listed in Hartman and Nelson, is also an example of a large genus that has undergone extensive speciation, resulting in an abundance of highly localized endemic species that are still being discovered at a steady rate. Among other significant examples are the following:

- *Astragalus* (Fabaceae) contains the largest number of novelties (43) listed in Hartman and Nelson, due in large part to the efforts of Rupert Barneby. *Astragalus* is also worth highlighting for the potential medicinal value of the new discoveries, given the known value of at least one Old World species, *A. membranaceus* Bunge. This species not only has a long history of use in Chinese traditional medicine, but it has also entered the American alternative medicine pharmacopoeia as an immune system enhancer, with some clinical evidence of activity in cancer patients with impaired immune responses (e.g., Chang et al., 1983; Kosuge et al., 1985). Intriguingly, this eerily approaches a case of fact following fiction, in that the hypothetical discovery of a cure for cancer in the form of *Astragalus*, only in this case a North American species, plays a key role in Duane Isely's fictionalized prognostication of what would happen if all taxonomists and their works suddenly disappeared (Isely, 1972).
- *Penstemon* (Scrophulariaceae): Where *Astragalus* has potential medicinal value, *Penstemon* has proven horticultural significance. The 29 novelties listed in Hartman and Nelson accordingly represent valued additions to the existing penstemon palette for rock-gardening enthusiasts, at least to the extent that they can be brought into cultivation without negatively impacting natural populations. In the Intermountain Region alone, seven species have been discovered and described subsequent to the 1984 treatment of *Penstemon* in the *Intermountain Flora*,

averaging one every two years (Holmgren, 1984, 1998).

- *Lesquerella* (Brassicaceae): Of the 83 species of *Lesquerella* in the late Reed Rollins's monumental synopsis of the Cruciferae of North America (Rollins, 1993), nearly half were authored or coauthored by Rollins himself over his long career, several in the book itself. As massive a compendium as this was, three additional species were discovered almost before the ink was dry: *L. lesicii* Rollins and *L. pulchella* Rollins from Montana (Rollins, 1995), and *L. tuplashensis* Rollins, K. A. Beck & Caplow from the Hanford Nuclear Reservation in Washington (Rollins et al., 1995). A short two years later, a fourth species, *L. vicina* J. L. Anderson, Reveal & Rollins, was published, with the epithet chosen in reference to the fact that the type locality was behind the home of a neighbor of one of the coauthors in Montrose, Colorado, growing in the sheep pasture (Anderson et al., 1997; J. Reveal, pers. comm. 1998).
- *Arabis* (Brassicaceae): The appearance of Rollins's (1993) compendium also triggered the description of a suite of four new *Arabis* from Canada, Alaska, and Greenland, as well as reports of numerous range extensions from the same region, all in the same publication (Mulligan, 1995). This example is significant in demonstrating that the northern latitudes are also full of floristic surprises, in spite of their generally fewer numbers of species. Farther south, *Arabis hirschbergiae* S. Boyd has recently been described from southern California, a stone's throw from a major highway (Boyd, 1998). All of these species are additions to the 17 novelties listed by Hartman and Nelson.
- *Eriogonum* (Polygonaceae): With 38 entries in Hartman and Nelson, *Eriogonum* has also proven to be an ongoing source of novelties, with one new species discovered on the Hanford Nuclear Reservation across the river from the new *Lesquerella*, as part of the same botanical survey (Reveal et al., 1995). An even more recent and dramatic example is provided by a pair of Friends of the Jepson Herbarium weekend workshops on *Eriogonum* in California in the summer of 1997, taught by *Eriogonum* specialist James L. Reveal. Of the 35 participants, mostly agency botanists and consultants, 3 ended up providing Reveal with additional undescribed taxa, leading to the quip that we should schedule a workshop on how to describe new species! In addition, Reveal confirmed that the variant of *E. nudum* Benth. that is the host plant for a federally listed butterfly, the Lange's Metal Mark *(Apodemia mormo langei* J. A. Comstock) is itself an undescribed taxon, bringing up to three the number of plants endemic to Antioch Dunes (a badly degraded inland dune complex on the edge of the Sacramento River delta in central California, less than an hour's drive from Berkeley; the other two are *Oenothera deltoides* Torrey & Fremont subsp. *howellii* (Munz) W. M. Klein and *Erysimum capitatum* (Douglas) Greene var. *angustatum* (Greene) Rossbach, both federally endangered.)
- *Carex* (Cyperaceae): *Carex* is noteworthy in that the majority of the 21 novelties listed in Hartman and Nelson, an average of 2 per year, are found in eastern North America. *Carex lutea* LeBlond, for example, was discovered in 1991 in North Carolina, where it is a rare endemic of wet savanna underlain by limestone. It is furthermore phytogeographically interesting in being a southern outlier (by 750 km) of a circumboreal species complex, possibly a relict from the Pleistocene. Associates of *C. lutea* include numerous other rare species, including Venus flytrap and an undescribed *Allium* (LeBlond et al., 1994).

Another recently described sedge, *C. juniperorum* Catling, Reznicek & Crins, is known from widely disjunct populations in Ontario, Ohio, and Kentucky. Although locally a groundlayer dominant, it was presumably overlooked because the inflorescences are nestled at the base of the plant and appear unexpectedly early in the season. In the protologue, the authors noted, "The recent discovery of this distinctive new species in a supposedly botanically well-known area suggests that even the flora of northeastern North America is not as well-known as is commonly supposed" (Catling et al., 1993).

(6) Scientifically significant discoveries

On top of the importance of cataloging the components of biodiversity for their own sake, many of the recently described species have carried significance beyond their intrinsic value. Some, such as *Neviusia cliftonii* and *Carex lutea*, pose interesting biogeographic puzzles. Others, including *Dedeckera eurekensis* and *Calochortus tiburonensis*, provide the key to unraveling phylogenetic questions (Reveal & Howell, 1976; Reveal, 1989a; Hill, 1973). *Dedeckera* is also significant as an ancient lineage postulated to have accumulated such a high segregational genetic load of heterozygosity that seed set is severely depressed (Wiens et al., 1989). Some additional examples:

- At the time of Keck's revision of *Ivesia* (Rosaceae) in 1938, *I. shockleyi* S. Watson was thought to be restricted to the Sierra Nevada of California and Nevada. Fieldwork by numerous botanists over the last two decades, however, has shown not only that *I. shockleyi* is scattered on mountaintops across the Great Basin, with a varietally distinct outlier in Utah (var. *ostleri* Ertter), but that a previously unknown complex apparently represents the low-elevation analog on unusual edaphic sites (Ertter, 1989). The low-elevation complex consists of several closely related entities with widely disjunct distributions: *I. rhypara* Ertter & Reveal var. *rhypara, I. rhypara* var. *shellyi* Ertter, and *I. paniculata* T. W. Nelson & J. P. Nelson. This example of island biogeography in a continental setting is interpreted in the context of Pleistocene-driven isolation and radiation, with one lineage retreating to isolated montane "islands" and the other finding a comparable niche in unusual edaphic sites at lower elevations. Molecular investigations with Christopher Baysdorfer (California State University at Hayward) are currently under way to further elucidate the resultant evolutionary pattern.

- *Verrucaria tavaresiae* R. L. Moe is noteworthy not only in being one of the few known marine lichens, but also the only lichen known with a brown algal phycobiont. Described in 1997, it is another example of "in our backyards," occurring in the intertidal zone around San Francisco, California (Moe, 1997).
- *Calycadenia hooveri* G. D. Carr (Asteraceae), described in 1975, possesses a chromosome arrangement almost identical to that of *C. villosa* DC., which is unlike that of other species in the genus. Reconstructions of chromosomal evolution based on molecular phylogenies of *Calycadenia* show that the ancestor of both aneuploid species lineages (which comprise the bulk of the genus) had a chromosome arrangement similar or identical to that of *C. hooveri* or *C. villosa.* Without *C. hooveri,* the reconstruction of chromosome evolution would have been equivocal (Carr, 1975; Baldwin, 1993).
- Probably the most surprising discovery involving North American ferns has been the realization that several species of Hymenophyllaceae and Vittariaceae in the eastern United States exist primarily as gemmiferous gametophytes, either growing north of the range of the sporophytes or, in a couple of cases, with sporophytes produced rarely if ever (Farrar, 1993a, b). Although vegetatively reproducing gametophytes have been known since 1888, their relative abundance (10% of all fern species worldwide) and significance has only become appreciated relatively recently (e.g., Farrar, 1974). Once gametophytes became the target of attention, three new species were discovered in the early 1990s: *Hymenophyllum tayloriae* Farrar & Raine, *Trichomanes intricatum* Farrar, and *Vittaria appalachiana* Farrar & Mickel.
- The liverwort genus *Pellia* (Metzgeriales), perhaps second only to *Marchantia* in the amount of attention previously given to liverwort genera, nevertheless provides a case where a critical look at the "common" species in the field yields unexpected results. Prior to 1981, only four species were recognized worldwide; in relatively quick succession, however, two new ones were published from eastern North America (*P. megaspora* R. M. Schust. and *P. appalachiana* R. M. Schust. [Schuster, 1981, 1991]), and one more is currently being described from Mississippi (R. Stotler, pers. comm. 1998).
- The bryophyte *Takakia* has been a puzzle since its discovery in 1951, at which time it was considered to be a liverwort. However, only vegetative and archegonial material was known, and attempts to induce fertile structures in cultivation met with failure. Sporophytic plants of *T. ceratophylla* (Mitt.) Grolle were finally encountered in 1990, in the course of fieldwork in the Aleutian Islands, firmly establishing *Takakia*'s identity as a moss (Smith & Davison, 1993). In essence, floristic discovery resulted in the transfer of a genus from one division (Hepatophyta) to another (Bryophyta)!

D. OTHER KINDS OF FLORISTIC SURPRISES

Although newly described novelties capture the imagination, they represent only the tip of the iceberg of floristic surprises, only the starting point for the comprehensive information that is truly needed for making difficult decisions in a scientifically informed manner. Even more incomplete than our knowledge of what species exist is our knowledge of where they occur, what their habitat requirements are, and similar questions that can only be answered by extensive fieldwork coupled with critical taxonomic analysis.

An excellent example of the incomplete and nonstatic nature of floristic information is provided by the recently revised flora of Missouri, in which the number of plants known to occur in a relatively well-studied state (with one of the oldest and largest herbaria in the country) has increased by nearly 12% since 1963, two-fifths of them native (Yatskievych, 1999). Current research on the flora of Mount Diablo, an isolated mountain and popular state park situated 25 miles east of San Francisco, California, shows an even more dramatic increase. In spite of the high quality of the original floristic effort (Bowerman, 1944), a recent update (Bowerman & Ertter, in press) has increased the known taxa by 25%, approximately half of which are native. Furthermore, several species in the 1944 treatment have been deleted or replaced, as a result of misidentified vouchers or changed circumscriptions. On the other hand, locally occurring variants of *Eriogonum*, *Lomatium*, *Calystegia*, and *Gilia* have the potential of being undescribed novelties (Ertter & Schultheis, 1998).

Some of the main categories of "floristic surprises" other than novelties are the following:

(1) "Presumed extinct"

Nearly as dramatic as the discovery of new species is the rediscovery of species that had been thought to be extinct. A recent example in California is that of the Ventura Marsh milk-vetch, *Astragalus pycnostachyus* A. Gray var. *lanosissimus* (Rydb.) Munz (Fabaceae), which was recently found in Ventura County, California, after being presumed extinct for 40 years. Local newspaper coverage referred to "A botanical resurrection" *(Ventura County Star,* 21 Aug. 1997) and "The Elvis Presley of flowering plants" *(Santa Barbara News-Press,* 15 Aug. 1997). The wildlife biologist who found the plant, Kate Symonds, was quoted in one account as noting, "It is more common to realize something is gone that used to be around, rather than finding something thought to be gone that is still in existence. It feels like a second chance for the species" *(Sacramento Bee,* 15 Aug. 1997). Ironically, the site was a former oil field waste dump, dispelling any notion that significant discoveries occur only in pristine habitats.

Coincidentally, another recently rediscovered Californian *Astragalus, A. agnicidus* Barneby, was also associated with disturbance. In this case, a plant that had been deliberately eliminated because of its perceived toxicity to livestock *(agnicidus* = "lamb-killing") reappeared when logging activity apparently triggered the germination of seeds that had lain dormant for decades (Hiss & Pickart, 1992). This example also serves to illustrate the difficulty of determining presence versus absence of a species at a site, let alone globally, even when no mature individuals are evident.

The systematic search for selected subsets of the 416 plants and animals that are considered potentially extinct in the United States was given a major boost recently by the Canon Exploration Grants Program directed by The Nature Conservancy (Stolzenburg, 1998; Anonymous, 1998). Although a depressing majority have not been relocated to date, there have been enough satisfying success stories to justify the program, in more ways than one. As evidence, consider the following story transmitted by the director of the program, Bruce Stein (pers. comm. 1998):

> "As I was jotting my note to you, a second 1998 find from the Canon program was slipped into my box. This just in from South Texas near Corpus Christi: *Paronychia lundellorum* B. L. Turner [Caryophyllaceae], which was last collected in 1958. As Bill Carr, the guy who refound it says (after finding it 9 paces from where he parked his car on his first stop), 'For me the experience was just another reminder of how few active botanists there are in Texas and how far behind the rest of the country we are in terms of tracking down our rarer resources . . . but maybe that's the point behind the Canon Exploration Grants Program. It provided the stimulus to get a warm body into the field to look for a species that, given the dearth of botanists in this part of the continent, might otherwise have remained enigmatic for who knows how long.' "

Not quite as exciting as the rediscovery of globally "extinct" species, but of potentially equal implications for land management, is the rediscovery of globally rare species that had been considered regionally extinct (i.e., extirpated). Excitement on the Mendocino National Forest in California has centered around the 1996 discovery of several populations of the federally threatened *Howellia aquatica* A. Gray (Lobeliaceae), previously known from California only on the basis of a single fragment collected in 1928 (Isle, 1997). Interpopulational genetic studies are currently under way to compare the California plants with those in Washington, Idaho, and Montana. In addition, another plant that had been thought extinct in California, *Ophioglossum pusillum* Raf. (Ophioglossaceae), was recently located adjacent to one *Howellia* population (D. Isle, pers. comm. 1998).

Even the reappearance of a not-so-rare species in a part of its range where it had seemingly disappeared can be newsworthy, as evidenced by the attention given to a population of *Mimulus tricolor* Lindl. found on the outskirts of Corvallis, Oregon (Holden, 1999). Although this species remained relatively common in the Central Valley of California, it had been assumed to be locally extinct in Oregon. As with *Astragalus agnicidus*, the reappearance of *Mimulus tricolor* after nearly 10 years demonstrates how long a species can persist in the seed bank, and accordingly how difficult it is to verify absence from a site.

(2) Distributional discoveries

More prosaic but gaining significance through sheer weight of numbers is the constant stream of distributional discoveries: major extensions in the known ranges of native species. Only the most dramatic are published (e.g., new state records); the bulk accumulate in the form of herbarium specimens. A recently verified, curiously overlooked example in the Jepson Herbarium (JEPS) is a specimen of *Luzula piperi* (Coville) M. E. Jones (Juncaceae) from northwestern California *(Ferlatte 349)*, over 600 km south of the nearest previously reported occurrence in northwest Washington (Hitchcock & Cronquist, 1973). A good example from eastern North America is *Schizandra glabra* (E. P. Bicknell) Rehder (Schizandraceae), the only American representative of an otherwise Asiatic genus. A population found in 1991, clambering over a sandstone cliff in southeastern Kentucky, is 250 km from the nearest of the previously known localities scattered across the coastal plain of the southeastern United States (D. D. Taylor, 1994).

More problematic is the recent discovery of *Limnanthes macounii* Trel. (Limnanthaceae) in a seasonally fallow field in west-central California (Buxton & Ornduff, 1998). Previously known only as a rare endemic of southeastern Vancouver Island in Canada, *L. macounii* was at one point presumed extinct (Hitchcock, 1961). What is currently under debate is whether this represents a surprising dispersal event, a previously overlooked natural range disjunction, or evidence that additional populations might exist in intervening sites (A. Ceska, pers. comm. 1998). Ornduff (pers. comm. 1998) supports the dispersal hypothesis, citing the reverse example of *Lasthenia minor* (DC.) Ornduff (Asteraceae) being found in northwestern Washington, over 1000 km north of the nearest naturally occurring population in central California (Vasey et al., 1994). The field in which the California population was found, which was probably significantly larger than the British Columbia population, was subsequently plowed prior to planting cabbage (Buxton & Ornduff, 1998).

Distributional discoveries are not restricted to single species within North America, but can occur as unexpected suites, as evidenced by the following:

- A special category is that of continental-level range extensions: species previously known only from Eurasia that are determined to occur in North America as well, not as introductions but as naturally occurring populations. William Weber (pers. comm. 1998) addressed the large number of Asiatic-Rocky Mountain disjunctions, many recently located, with the comment: "J. D. Hooker was certainly right when he was shocked to see some of his Asiatic things on his five days in the Rockies [in 1877]; sadly, Asa Gray evidently was on a vacation/picnic and didn't recognize that there might be a high latitude component to his Tertiary discoveries in eastern North America."

Continental-level range extensions are not restricted to the arctic and alpine regions, however, but can also be found farther south. For example, specimens from Texas and Arizona previously confused with *Ophioglossum engelmannii* Prantl (Ophioglossaceae) turned out to be conspecific with the widespread Old World species *O. polyphyllum* A. Br. (Zech et al., 1998). More recently, *Eleocharis mamillata* H. Lindb. (Cyperaceae) has been determined to be native and widespread in boreal North America (S. G. Smith & T. Gregor, in prep. 1998).

While continental-level range extensions are noteworthy in vascular plants, they are more routine in bryophytes and lichens (B. Murray, pers. comm. 1998). Even here, however, some examples stand out from the crowd, such as *Aspicilia moenium* (Vainio) Thor. Described in 1986 from Scandinavia, where it often occurs on the mortar of old churches, this lichen was unexpectedly encountered on an old retaining wall connected to the building that houses the COLO herbarium in Boulder, Colorado (Weber, 1996). The account of the discovery of this population amusingly addressed the quandary of how to obtain a decent specimen from an intact structure, solved with the cooperation of Facilities Management staff.

- Conifers are perhaps the best-mapped group of plants in North America (e.g., Little, 1971), being both conspicuous and economically significant. Nevertheless, recent fieldwork by David Charlet has determined that 43% (90) of the 207 conifer-bearing mountain ranges in Nevada harbor at least one more conifer than previously reported, and 12% (24) have had two to four species added to the known complement (Fig. 4). Approaching the same data from a different angle, of the 22 species of conifer known to occur in Nevada, 14 occur on at least one more mountain range than had previously been reported, resulting in 15 new county records in Nevada's 13 western-size counties (Charlet, 1996, pers. comm. 1998).
- On the Pacific Coast, ongoing surveys of near-shore banks that rise to within 30 m of the surface are revealing a hitherto unsuspected and remarkably uniform assemblage of around 40 species of marine macroalgae (seaweeds), extending from Puget Sound to northern Baja California. Included in the assemblage are noteworthy range extensions such as *Pleurophycus gardneri* Setch. & D. A. Saunders (Laminariales), before 1970 recorded only as far south as Oregon but now known to be dominant at depths of 40 m off the central California coast (Kjeldsen, 1972; P. Silva, pers. comm.

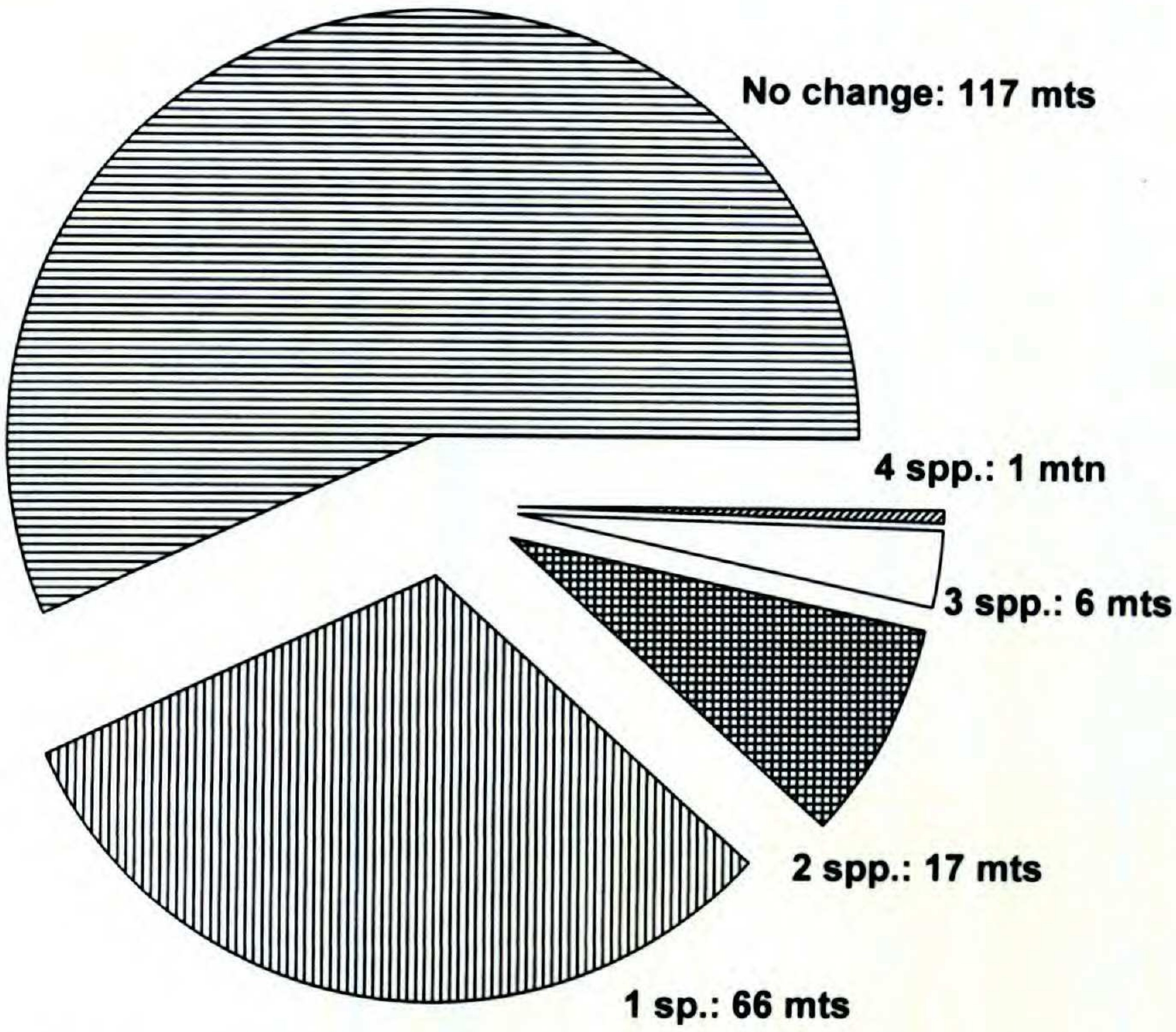

Figure 4. Proportional representation of mountain ranges in Nevada in which additional species of conifers beyond those previously recorded were located during the Charlet survey, 1988–1998 (fig. prepared by D. Charlet).

1998). Although the kelp is readily identifiable, the existence of these southern populations was not apparent because the plants grow at depths that are undisturbed by even violent storms and are accordingly seldom cast ashore.

- Probably the biggest distributional surprise in fungi is the discovery that the occurrence of mushrooms above ground and the fungal species diversity below ground, as determined by molecular analysis of hyphal fragments in the soil, can be completely independent (Gardes & Bruns, 1996). As a result, determining the distribution and rarity of various fungal species presents a challenge well beyond that posed by vascular plants and bryophytes.

(3) Declines and invasions

Whereas all of the preceding examples involve changes to our knowledge of the distributions of species, there are also actual changes in the distributions themselves. On the one hand are significantly diminished ranges, in which historical occurrences documented by herbarium vouchers no longer reflect current distributions. An example is afforded by *Horkelia cuneata* Lindl. subsp. *puberula* (Greene) D. D. Keck (Rosaceae), in which a significant portion of the historically documented range has disappeared under Greater Los Angeles (Ertter, 1995). This kind of distributional attrition has obvious conservation implications, but is extremely difficult to become cognizant of, such that it is theoretically possible for a species to go extinct before its endangered status has even been noted.

On the flip side, and often contributing to the decline of native species, is the spread of species into areas where they did not historically occur. The explosion of aggressive non-natives is of increasing concern due to the various negative impacts such invasions can have on both natural and economic systems. The sheer numbers of newly reported non-natives can be mind-boggling, though it is difficult to determine which are new occurrences and which have simply been overlooked, given that naturalized species are historically undercollected. Vincent and Cusick (1998) documented 70 additions to the Ohio flora, and also emphasized the fact that the non-native component of floras is dynamic, with species appearing, flourishing, and occasionally disappearing. Even in the region around the United States' national capital, which has been rather systematically collected since the 1690s, recent surveys have resulted in the discovery of seven new plant records for Maryland (including two native *Carex*), five of which came from the grounds of the Agriculture Research Center in Beltsville (J. Reveal, pers. comm. 1998).

In California, over 70 non-native species are currently known to have become naturalized beyond those included in *The Jepson Manual* (Hickman, 1993; F. Hrusa, pers. comm. 1998). As dramatic evidence of how difficult such new occurrences are to keep abreast of, at least 19 occur within an hour's drive of the building in which *The Jepson Manual* was edited. Five are even fully naturalized in the Berkeley campus natural areas (*Geranium rotundifolium* L., *Geranium lucidum* L., *Geranium purpureum* Vill., *Hypericum androsaemum* L., and *Hedera helix* L. subsp. *canariensis* (Willd.) Cout.), and at least three others have already achieved significant pest status in local parklands (*Dittrichia graveolens* (L.) W. Greuter, *Limnobium laevigatum* Willd., and *Maytenus boaria* Molina). The dynamic nature of California's non-native flora, as well as the difficulty of obtaining reliable information on current occurrences, has been addressed by Rejmanek and Randall (1994).

E. WHY NOT FOUND BEFORE?

The preceding examples should serve to emphasize that the era of significant floristic discoveries in North America north of Mexico is far from over, despite perceptions extending back to the mid-19th century. Even the initial cataloging of novelties is incomplete, to the extent that conspicuous shrubs along highways are still being discovered and described as distinctive new species. The comprehensive mapping of known species, including newly invasive pest plants, is equally erratic, at a time when such information is sorely needed to make sound science-based land-management decisions.

The inevitable question arises as to *why* so much of our floristic heritage has remained unexplored, uncataloged, and unmapped. The principal answer is relatively straightforward: it's a big job! As a result, and as many of the previous examples testify, a primary factor contributing to ongoing floristic discoveries is the number of people who are actively scouring the field. Fortunately, this is by no means limited to professional scientists in academic institutions, but instead depends heavily on the collective efforts of agency biologists, environmental consultants, and native plant enthusiasts (Ertter, 1995; Yatskievych, 1999). Representatives of this diverse group are highlighted in a later section of this paper.

However, the number of people actively searching is only one aspect of floristic discoveries. The remaining portion of this paper accordingly addresses other assumptions that have influenced the cataloging of North American plants, both historically and currently.

ASSUMPTION 2: HYPOTHESIS-FREE DESCRIPTIVE SCIENCE

One key assumption is the common and recurring one that taxonomy and floristics, as examples of "descriptive" science, are not intrinsically scientific, at least as contrasted to the more overtly experimental sciences. This assumption has directly influenced hiring, funding, and promotional decisions, which in turn determines research priorities. Although the full structure of my argument is beyond the scope of the current paper, I will nevertheless posit that science is most definitely involved in all aspects of taxonomy and floristics, complete with the full panoply of falsifiable hypotheses and scientific methodology, even when these are not explicitly expressed.

A. DESCRIPTIVE HYPOTHESES

The assumption that recognizing and "describing" novelties is a simple descriptive process reflects an outdated understanding of biodiversity as consisting of discrete, pre-Darwinian quanta, lacking significant internal variation and separated from one another by inviolate boundaries (Ertter, 1997a). This was noted by Constance (1971: 22) over a quarter-century ago: "Although the doctrine of 'Special Creation' of species has lacked any scientific status for a hundred years, many people seem still to be thinking in terms of a finite number of objects created once and for all, and which merely have to be recognized, described, and named."

Much of the confusion has a semantic underpinning, in that "describing" a species is by no means equivalent to "describing" a concrete individual item. To place species "description" in the explicit framework of set theory and hypothesis generation, the standard phrase:

> "A description of new species *Alpha beta*, which differs from other species of *Alpha* in characters X, Y, and Z"

can be expanded into the complex hypothesis:

> "There exists a previously undiscerned component of natural diversity that falls within the biological parameters of the current species concept, which is hereby coded as species-set *Alpha beta*. As both support for and corollary of this hypothesis, all members of species-set *Alpha beta* are hypothesized to possess biological attributes X, Y, and Z, whereas all members of other species-sets in genus-set *Alpha* are hypothesized to lack this combination of biological attributes."

Furthermore, not only are species and their circumscriptions best understood as complex hypotheses, but so also are such seemingly "factual" statements as "Leaves (2.4)3–5(6.1) cm long," which is in actuality shorthand for the predictive statement: "Based on a measured subset, leaf-length for ALL leaves for ALL members of species-set *Alpha beta*, past, present, and future, is predicted to be at least

2.4 cm long but no more than 6.1 cm long, with the majority falling in the 3–5 cm range."

In both cases, the first phrase is obviously much less cumbersome, but the expanded version more clearly expresses the fact that nested hypotheses are involved, all of which are subject to subsequent testing and modification whenever new data are obtained, most often in the form of new collections of plants that "haven't read the book." Even the identification of an individual specimen can be worded to reflect the complexities of set-assignment, to wit: "The specimen in hand possesses the diagnostic biological attributes that characterize members of the set *Alpha beta.*"

B. PARSING SPECIES

In other words, rather than being routinely simple and straightforward, the task of parsing biodiversity into taxonomic components can be a significant intellectual challenge. As a result, although blatantly distinct species are still being encountered, the majority of recently described novelties are determined to be such only after an extended and detailed comparison with other species, often requiring a wholesale re-thinking of existing taxonomic frameworks. In these cases, it is not at all intuitively obvious what qualifies as a "previously undiscerned component of natural diversity" that falls within "the biological parameters of the current species concept," based on some yet-to-be-determined suite of diagnostic biological attributes.

An excellent example is provided by *Potentilla morefieldii* Ertter (Rosaceae), in which multiple collections had accumulated and been variously identified as (= assigned to species-sets) *P. pseudosericea* Rydb., *P. pensylvanica* L., or *P. breweri* S. Watson (Ertter, 1992). The non-obvious nature of the taxonomic hypothesis that an undescribed species was involved is evident from the fact that an earlier numerical analysis of phenetic variation failed to uncover the novelty (Johnston, 1980). The species is actually quite distinct, once the appropriate diagnostic attributes are highlighted.

In fact, it is more the norm than the exception for the first few collections of a species to be shoehorned into existing species-sets, generally with modifications to the "biological attributes" hypotheses. Shevock and Taylor (1987), for example, noted a range of 1 to 121 years between earliest herbarium specimen and publication in their analysis of California novelties, with an average of 41 years! An even greater span is noted by Hartman and Nelson (1998), with the oldest holotype over 200 years old, and 60% of the novelties having type specimens over 10 years old. However, Hartman's and Nelson's statistics underrepresent the actual range between initial collection and date of publication, in that the earliest collection is not always chosen as holotype. *Monardella beneolens* Shevock, Ertter & Jokerst (Lamiaceae), for example, was typified on a 1986 collection *(Shevock, Bartel & York 11727)*, but included among the paratypes was an 1896 collection *(Purpus 1866)* that had languished in the undetermined-to-species folder for nearly a century (Shevock et al., 1989). This example also illustrates that the distinction between a novelty based on a new discovery and one resulting from a novel analysis of existing specimens is not always clear-cut, in that the collection of an undescribed *Monardella* on a 1986 "Inter-Institutional Haybaling Expedition" is what triggered the herbarium search that uncovered the older specimen.

Nor does the proposing, testing, and rejection of alternate hypotheses end once new species are described. For my doctoral work, I essentially tested the hypothesis proposed by my advisor that a series of annual *Juncus* (Juncaceae) did not meet the criteria for recognition as distinct species, as had been previously proposed (Hermann, 1948), but rather "appear to be mere technical variants, often locally constant as in self-pollinated groups in other genera, but with widely overlapping ranges and similar habitat requirements" (Cronquist, 1977: 64). As it turned out, my doctoral work not only provided support for all of Hermann's hypothesized species except one, but gave evidence of three additional novelties (Ertter, 1986). Although I enjoy the notoriety that comes with being able to say that I proved Art Cronquist wrong *and got him to admit it,* I will also submit that his was a perfectly legitimate hypothesis *based on the information available to him at the time.*

C. FLORISTIC MODELS

The last example introduces the concept of monographs and floras as representing complex models encompassing multiple species, whose individual identities depend on the larger context. As a result, the binomial *Juncus kelloggii* Engelm. codes for three very different entities, depending on whether it is in the context of Hermann's, Cronquist's, or Ertter's model. In this example, sufficient evidence has been accumulated to support one model over the alternatives, but this is not always the case. A contrasting example is presented in Table 1, a partial list of corresponding units of the taxonomically challenging genus *Po-*

Table 1. Concordance of selected species from alternate taxonomic models of *Potentilla* (Rosaceae) in the Intermountain West (= portions of Arizona, California, Idaho, Nevada, Utah, and Wyoming), as proposed by contemporaneous authors: N. H. Holmgren (1997), B. Ertter (treatment for *Flora of North America,* in prep.), J. Soják (unpublished 1995 synopsis of North American tribe Potentilleae), and S. L. Welsh (1993; Utah only, "n/a" indicates entities not occurring in Utah). Table includes some unpublished combinations used by Soják.

Holmgren (1997)	Ertter (in prep.)	Soják (unpublished)	Welsh (1993)
Potentilla pensylvanica	Potentilla pensylvanica	Potentilla pensylvanica	Potentilla pensylvanica
	var. strigosa	var. pensylvanica	var. pensylvanica
Potentilla bipinnatifida	Potentilla bipinnatifida	Potentilla litoralis	
	var. bipinnatifida	var. litoralis	
(= pensylvanica)	var. ovium	var. ovium	
Potentilla pseudosericea	Potentilla pseudosericea	P. hookeriana	(pseudosericea n/a)
		var. hookeriana	(= rubricaulis)
(= rubricaulis)	[to be determined]	var. paucijuga	var. paucijuga
Potentilla rubricaulis	[to be determined]	P. rubricaulis	Potentilla rubricaulis
Potentilla concinna	Potentilla concinna	Potentilla concinna	Potentilla concinna
	var. concinna	var. concinna	n/a
(= rubricaulis)	[to be determined]	?	var. modesta
(= concinna)	(= concinna)	Potentilla × concinnaeformis	
		var. concinnaeformis	
		var. beanii	var. proxima
Potentilla bicrenata	Potentilla bicrenata	P. concinna var. bicrenata	var. bicrenata
Potentilla diversifolia	Potentilla diversifolia	Potentilla × diversifolia	Potentilla diversifolia
var. diversifolia		var. diversifolia	var. diversifolia
(= concinna)		var. proxima	P. concinna var. proxima
(= diversifolia)	Potentilla glaucophylla	Potentilla glaucophylla	
		var. glaucophylla	
var. perdissecta	[to be determined]	var. perdissecta	n/a
Potentilla gracilis	Potentilla gracilis	Potentilla fastigiata	Potentilla gracilis
var. fastigiata	var. fastigiata	var. fastigiata	var. glabrata
		var. hallii	
		var. jucunda	
	var. permollis	var. permollis	
	var. brunnescens	Potentilla nuttallii	var. brunnescens
var. flabelliformis	var. flabelliformis	Potentilla flabelliformis	n/a
var. elmeri	var. elmeri	Potentilla pectinisecta	var. elmeri
		var. pectinisecta	
		var. comosa	
var. pulcherrima	Potentilla pulcherrima	Potentilla × pulcherrima	var. pulcherrima
		var. pulcherrima	
		var. wardii	
		Potentilla filipes	
		var. filipes	
		Potentilla × lupina	

tentilla (Rosaceae) occurring in the Intermountain West, as proposed by four different specialists, all with access to the same data. The lack of consensus is not an indication of an inability to agree on standards, of taxonomists not being able to "get their acts together," but is rather a reflection of four equally valid models for which insufficient evidence currently exists to strongly support one over the others.

An even larger-scale example of a floristic model is provided by the numerous differences between the comprehensive list of California taxa as summarized in *The Jepson Manual* (Hickman, 1993) and the contemporaneous *Inventory of Rare and Endangered Plants of California* (Skinner & Pavlik, 1994). As analyzed by Skinner and Ertter (1993), the differences result not from one or the other being intrinsically "wrong," but from legitimate philosophical differences in the rationales behind the two publications. The goal of the *Manual* was to maximize the likelihood of unequivocal identification, while that of the *Inventory* was to highlight units of plant diversity that merited conservation attention. These different goals resulted in different models; in those situations where there was legitimate room for alternate taxonomic hypotheses, the *Manual* tended to lump where the *Inventory* tended to split, so as to avoid "lamentation over taxa that are shown to be distinct only after their disappearance" (Skinner & Ertter, 1993: 27).

D. NOVELTIES IN WAITING

Nevertheless, even within an *Inventory*-type model emphasizing the smallest defensible units as worthy of taxonomic recognition, the requirements for scientifically legitimate, peer-reviewed publication of novelties demand rigorous support for the proposed taxonomic hypothesis. For example, the *Draba* study by Windham and Beilstein (1998a, b), discussed in an earlier section, clearly demonstrates how sophisticated an analysis is often required even for the recognition of unequivocally distinct species. In addition, although many of the highlighted novelties prove that radically different species are still being discovered, the truth is that the majority of blatantly distinct and/or readily encountered taxa have already been described. As a result, ferreting out the remainder will require not only continued exploration, but also increasingly rigorous scientific analysis.

Because of this, there currently exists an unknown number (50? 200? 500?) of potential novelties from North America that members of the taxonomic community are collectively aware of, but which need to be extensively tested before being written up for publication. I am personally aware of several possibilities, in *Juncus, Rosa, Potentilla, Horkelia, Eriogonum, Montia,* and *Lomatium,* and in fact have as a rule of thumb that any complex group that has not been intensively monographed recently is likely to harbor undescribed novelties. However, all of these possibilities are just that, possibilities, and will require a significant investment of research effort to determine if they are rigorously supportable as taxonomic hypotheses. In other words, the limiting factor for many novelties is not whether they have been encountered or not, but the existence of persons with sufficient expertise, motivation, and time to undertake the necessary scientific analysis.

ASSUMPTION 3: ACADEMIC PARTICIPATION

To recapitulate, although the initial discovery of novelties does not require professional training, the analysis of potential novelties is another matter, in which scientific expertise plays a crucial role. Most collectors accordingly rely on the network of taxonomic specialists, who in turn rely on the analytical resources represented by herbaria and botanical libraries, as well as established and innovative technologies. These resources, along with the custodianship and transmission of the extensive legacy of taxonomic knowledge, skills, and techniques, have traditionally fallen within the domain of plant taxonomy in an academic setting, including research museums and botanical gardens.

A. THE ROLE OF REGIONAL FACULTY

Although university-based faculty are only one category of professional expertise (versus, for example, research staff and museum-based professionals), they are highlighted here on the grounds that they are generally assumed to provide the backbone of the rigorous taxonomic analysis described in the previous section, especially faculty at those universities with large herbaria that occur in the regions where most novelties are being discovered. In this context, it is illuminating to analyze the current status of persons in table 4 in Hartman and Nelson (1998): "Individuals who authored six or more novelties of North American plants during the past two decades," according to the categories in Table 2. Of the 56 individuals listed, the two largest categories, both in number of individuals and number of novelties, are "Emeritus (or nearly so)" and "Deceased." Together, the two categories account for 60% of the novelties described from 1975 through 1994. In contrast, faculty who are currently mid-career account for only 6% of the novelties.

To pursue the specific question of novelty description by regionally based faculty further, I polled plant systematists at universities who matched all of the following criteria:

(1) Located in the contiguous western United States (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Washington, Wyoming), a region with a high rate of ongoing discoveries.
(2) Located at a university or college with an herbarium of at least 20,000 specimens, representing the equivalent of a fully equipped laboratory for doing taxonomic research on the local flora.
(3) Self-defined as vascular plant systematist (versus ecologist, plant population geneticist, etc.) OR serving as director/curator of the departmental herbarium.
(4) Department-based (versus adjunct) faculty appointment, excluding emeriti, as those persons

Table 2. Current status of individuals listed in table 4 of Hartman and Nelson (1998), "Authors of 6 or More Vascular Plant Taxa North America North of Mexico from 1975 through 1994." The first column gives the total number of individuals in each category, and the second column is the sum total of novelties described by these individuals. Authors describing fewer than 6 novelties are not included in the tally, nor are novelties described by these individuals.

Current status	No. (percent) of persons	No. (percent) of novelties
Deceased	13 (23%)	174 (21.4%)
Faculty		
Emeritus (or within several years)	12 (21%)	316 (38.8%)
Early to mid-career	5 (9%)	50 (6.1%)
Non-faculty academic staff	5 (9%)	65 (8.0%)
Museum staff	9 (16%)	81 (9.95%)
Government agency biologist	4 (7%)	46 (5.65%)
Environmental consultant	2 (4%)	29 (3.6%)
Private individual	2 (4%)	22 (2.7%)
Unknown	4 (7%)	31 (3.8%)
Total	56	814

whose hiring, promotion, and tenure are determined by current departmental expectations.

The specific question addressed was whether each respondent had described (a) zero, (b) one, or (c) more than one vascular plant novelty from anywhere within the contiguous western United States. The number of responses to this survey was gratifying, but the collated results (Table 3) are thought-provoking. Of the 56 persons included in the survey, over half had not described a single novelty from the region, and over half of the remainder had only described a single novelty (or at least had one in press). In several cases, this solitary western novelty was described during the course of graduate work but not since attaining faculty status. Only 10 qualifying faculty members in the entire region have described more than one novelty from the region, and several of these persons are within a handspan of years from retiring.

Furthermore, of the 48 western universities with significant herbaria, 5 currently lack faculty-level vascular plant systematists, including 2 that house the largest herbaria for their respective states (University of Montana, Missoula; University of Nevada, Reno). In Oregon, the two primary herbaria were recently combined, eliminating the position of plant systematist at the University of Oregon, Eugene. One state (Colorado) currently lacks a faculty-level plant systematist who has published any novelties from the region, while four others (Arizona, Montana, Nevada, Washington) can claim only one faculty systematist who has described a single novelty from the target area. This in a region in which 813 taxa were described from 1975 through 1994, around 41 per year, with no evidence of tapering off (Hartman & Nelson, 1998).

B. ACADEMIC SELECTION PRESSURES

The purpose of this survey was not to call into question the scientific productivity of the respondents, who are all actively pursuing a commendable diversity of significant research in plant systematics, including describing novelties from other parts of the world. Nor is it intended to slight the significant contributions of individuals outside the admittedly narrow survey criteria, professional and otherwise. The survey does, however, undermine any assumption that faculty-level plant systematists at the best-equipped western universities comprise the major pool of expertise in ongoing efforts to analyze and describe the unknown elements in a novelty-rich regional flora.

Moreover, there is evidence that this is not a statistical curiosity, but rather an indication that the current academic infrastructure actually discourages such participation. Several respondents indicated that they knew of undescribed regional novelties, but could not justify the research time and effort required to publish them. In the words of one such respondent, "the value of new species descriptions in terms of professional prestige and satisfaction of university administrators (who control raises and promotions) seems low relative to other publications that could be generated in a similar

Table 3. Participation of current vascular plant systematist faculty in the contiguous western United States in the description of regional novelties (Ertter, unpublished data). Column 1 is the number of universities or colleges in each state with significant herbaria (defined here as at least 20,000 specimens). Column 2 is the number of department-based (vs. adjunct) vascular plant systematists, and non-systematists actively serving as herbarium director. Columns 3, 4, and 5 are the number of persons in column 2 who have described, respectively, (a) zero, (b) one, or (c) more than one vascular plant novelty from anywhere within the contiguous western United States, including novelties in press. Percent representation among these three categories is given in parenthesis after summary totals. Column 6 is the total number of novelties from each state published 1975 to 1994, tallied in table 8 of Hartman and Nelson (1998).

			Novelties described			Total
	Institutions	Faculty	0	1	>1	novelties
Arizona	3	3	2	1	0	60
California	16	14	8	2	4	223
Colorado	3	3	3	0	0	33
Idaho	3	4	2	2	0	33
Montana	2	1	0	1	0	12
Nevada	2	1	0	1	0	64
New Mexico	2	3	0	2	1	41
Oregon	2	3	1	2	0	44
Texas	8	14	11	1	2	75
Utah	3	3	0	1	2	183
Washington	3	5	4	1	0	13
Wyoming	1	2	0	1	1	32
Totals	48	56	31	15	10	813
(percentages)			(55%)	(27%)	(18%)	

period of time." In effect, the publication of regional novelties is not only of little value, it is actually counterproductive to career development in the current academic environment. Paradoxically, the fact that the amount of time and effort it takes to publish a novelty can be equivalent to that needed for other research activities in itself provides evidence that describing novelties is not the trivial activity it is routinely perceived to be.

I find it illuminating to compare the preceding quote with another, from nearly a half century ago: "If taxonomy and taxonomists are to regain some of their lost prestige—and they have lost a great deal—it seems obvious that mastery of a local flora, an ability to recognize characteristic members of the more common plant families, a familiarity with the rules of nomenclature, and the capacity to write descriptions are bound to prove woefully inadequate" (Constance, 1951: 229). We have apparently come full circle, where the skills that were once the *sine qua non* of a practicing taxonomist have apparently gone from being "inadequate" to being irrelevant. Or, at best, these former skills are assumed to come as part of the "systematist package," overlooking the tenet otherwise well known to biologists that "you get what you select for." Admittedly, the above analysis is only a single slice in time, but it nevertheless strongly suggests that the activities that result in the publication of regional novelties are NOT among those currently being selected for within academia, and as a consequence are de facto being selected against.

C. WHO IS DOING THE WORK?

The question then arises: If not faculty-level systematists at the best-equipped regional universities, who is responsible for generating the 41 novelties per year in the contiguous western United States? Obviously there are numerous people who are discovering and describing western novelties other than those targeted here, who I have neither surveyed nor otherwise statistically analyzed. The major categories, however, would include the following: emeriti plant systematists; museum-based plant systematists, often with adjunct appointments at nearby universities; faculty-level plant systematists at less well-equipped regional university and colleges (i.e., with herbaria having less than 20,000 specimens); plant systematists outside of the region; non-faculty research and curatorial appointments; non-systematists (e.g., ecologists, population geneticists); government agency biologists; biologists working for the private sector, mostly as environmental consultants; and amateur enthusiasts.

Certainly the academic and museum-based categories play significant roles, which should not be underestimated. What I wish to draw attention to at this point, however, is the high degree of participation by professionals and amateurs outside of academia, many of whom have an exceptional eye for novelties and a serious commitment to floristic undertakings. As representative examples, some of the more outstanding are spotlighted below:

(1) Government agency biologists

Beginning with his stint in 1979 as botanist for the Sequoia National Forest in California, James R. Shevock has now tallied 6 vascular plants and 1 moss named in his honor, 12 others that he has authored, and several undescribed novelties in various stages of publication. Many of his earlier novelties were encountered by his being the first botanist each year on newly constructed portions of the Pacific Crest trail, which ended up bisecting a population of *Allium shevockii* McNeal that is still one of the only populations known. While retaining a focus on the southern Sierra Nevada, Shevock's botanical interests have subsequently expanded to include mosses and lichens, with *Orthotrichum shevockii* Lewinsky-Haapasaari & D. H. Norris (Orthotrichaceae) being the most recent addition to his eponymous tally. The protologue credits Shevock with "opening the eyes of the junior author to the bryophyte riches of the southern Sierra," a significant accomplishment considering Norris's extensive expertise with the California bryoflora (Lewinsky-Haapasaari & Norris, 1998). Shevock's agency career has likewise expanded; as Regional Botanist, he prepared the status report on rare and endemic plants for the Sierra Nevada Ecosystem Project (Shevock, 1996), and he has recently moved on to become Associate Regional Director of the National Park Service. Shevock's botanical explorations are accordingly now confined to weekends and vacations, but have not noticeably slowed as a result. On a 1996 foray (a.k.a. "death march") to an isolated marble ridge, he and protégé Dana York (botanist for Death Valley National Park) discovered three novelties in a single day: *Heterotheca monarchensis* D. A. York, Shevock & Semple, *Gilia yorkii* Shevock & A. G. Day, and a still-undescribed *Eriogonum*.

(2) Environmental consultants

The tragic death of James D. Jokerst, who drowned while trying to retrieve the family canoe, cut short the career of one of the persons who did the most to convert environmental consulting into a legitimate career for skillful, well-trained botanists. While working full-time for the environmental consulting firm Jones & Stokes Associates, Jokerst nevertheless found time to develop expertise in the Lamiaceae, preparing treatments of several genera in *The Jepson Manual* (Hickman, 1993), including the notoriously difficult *Monardella* (Magney, 1996). He also authored or coauthored three novelties: *Acanthomintha obovata* subsp. *cordata* Jokerst, *Monardella beneolens* Shevock, Ertter & Jokerst, and *Pogogyne floribunda* Jokerst. While doing a botanical survey in 1985, Jokerst discovered an unusual gold-flowered *Trifolium*, which was posthumously named in his honor (Vincent & Morgan, 1998). According to Vincent (pers. comm. 1998), the clover "was found in an area that A. A. Heller had collected at several times, but never early enough in the season!"

Environmental consultants in general are playing an increasingly significant role in discovering novelties, as the persons most likely to have access to poorly botanized areas. As prime examples, the discoveries of *Yermo xanthocephalus*, *Twisselmannia californica*, and *Neviusia cliftonii* were connected to environmental survey efforts. Unfortunately, a great many biological consultants lack the training or orientation needed to recognize potential novelties, and may in fact be discouraged from taking note of anything but a mechanically generated list of rare species determined to be potentially present at a given site. This practice is based on the dangerously flawed assumption that previously existing knowledge is an accurate indication of likely occurrence, an assumption at odds with the theme of "floristic surprises." As summarized by S. Boyd (pers. comm. 1998), discoverer of *Sibaropsis* and other novelties in the course of doing environmental surveys:

> "There is the strong possibility that other botanical gems are being overlooked by overworked, and sometimes undertrained, botanical consultants too myopically focused on the punchlist of expected sensitive species. It seems to me much better to approach any botanical inventory from the point of 'what is present overall?' vs. 'which sensitive plants are present?' I wonder how many other undescribed taxa have been overlooked and subsequently lost to habitat destruction."

(3) Amateur enthusiasts

Among the more unexpected of the amateur enthusiasts is Lowell Ahart (Geary, 1978), a sheep rancher who started out cataloging the plants of his ranch and has since moved on to county floras, collaborating with retired zoology professor Vern Oswald (e.g., Oswald & Ahart, 1994). Two plants from his ranch have been named after him (*Juncus leio-*

spermus var. *ahartii* Ertter, *Paronychia ahartii* Ertter), and an *Eriogonum* is also being named in his honor (J. Reveal, pers. comm. 1997). When Ahart brought the undescribed *Paronychia* to my attention, begging that someone provide a name for it so he could complete the checklist of his ranch, it had actually been known for some years but had been assumed to represent yet one more introduced Eurasian annual. However, by then a worldwide monograph of the Paronychiinae was available (Chaudhri, 1968), making it evident that an anomalous undescribed species was involved, whose affinities are still unclear (Ertter, 1985).

(4) Other para-academics

A final example of expertise outside of academia is provided by Arnold (Jerry) Tiehm, who has an advanced degree in botany and previous professional experience (e.g., curatorial staff at The New York Botanical Garden). For the last several years, however, Tiehm has earned his living as bell captain and limousine driver at the Peppermill Casino in Reno, Nevada, doing his botanizing on his days off. At last count he has nevertheless made the type collections of 19 species (Holmgren, 1998), approximately one per year, several of which are named after him. Probably the most significant is *Stroganowia tiehmii* Rollins, the single North American representative of a genus otherwise confined to central Asia (Rollins, 1982). It also qualifies as another "in our backyards" discovery, not encountered until 1980 even though occurring only a few miles off a well-traveled highway 20 airmiles east-southeast of Reno.

D. IS THE POOL SUFFICIENT?

These highlighted individuals are only a sampling from a large pool of talented and dedicated individuals operating outside of an academic setting, including some who not only discover but analyze and describe their own novelties. When these para-academics are combined with museum-based systematists, faculty at smaller institutions, and non-faculty research staff, it might accordingly be argued that the existing pool of expertise is sufficient, and that faculty systematists at the larger universities should appropriately be encouraged to address avenues of research that cannot be handled by others.

While confirming my enthusiastic support for a diversity of individual research interests within academia, and likewise for the active participation of individuals outside of the academic mainstream, I will nevertheless argue (as have others, such as Kruckeberg, 1997) that a core of professional plant systematists will continue to play an indispensable role in the task of discovering, analyzing, and describing the remaining unknown element in the North American flora, as well as critically evaluating new information accumulated about previously described species. In other words, rather than being made redundant by the para-academic network, an active core of professional systematists is integral to the proper functioning of the network. Furthermore, a significant percentage of this professional core needs to be housed at the large regional herbaria, especially in the West and Southeast where the majority of floristic discovery is occurring.

The obvious argument for academic participation is, of course, to provide the formal systematic training for all other participants in the network, including agency biologists and environmental consultants. Perhaps even more critical, however, is the reality that regionally based professional systematists represent the essential source of quality control and accessible scientific expertise to turn to when non-systematists encounter "plants that haven't read the book." Furthermore, para-academics who analyze and describe their own novelties generally do so only after a period of "apprenticeship" with a regionally based, practicing taxonomist. In this regard, it is unsettling to realize how many of the regional professionals who provided early encouragement and training to the current crop of active para-academics are now retired or deceased. A prime example of the latter is the late John Thomas Howell of the California Academy of Sciences, who provided significant encouragement to most of the individuals highlighted above.

Howell also represents the category of museum-based research staff that is becoming increasingly important in maintaining the role of the professional core. As significant as this contribution is, however, museums and botanical gardens are too few in number to provide complete regional coverage, and are also less likely to be involved in formal training. At the same time, the suggestion that descriptive systematics should be relegated to smaller universities and colleges runs counter to the fact that the major herbaria are generally at the larger universities. The continued participation by major regional universities is therefore essential to the ongoing task of discovering and analyzing the regional flora. If this task is in fact incompatible with academic realities currently facing faculty systematists (and not just a matter of erroneous perceptions), then it is imperative that alternate ways to ensure such participation be investigated, perhaps involving direct funding or collaborative programs with state or federal land-management agencies.

E. THE TAXONOMIC LEGACY

Approaching the situation from a different angle, there is the question of the taxonomic legacy, a term used here to refer to the material resources (i.e., regional herbaria and associated libraries); the fundamental knowledge, skills, and techniques for floristic analysis; and the setting of scientific standards, generally in a peer-reviewed context. Custodianship of this legacy, developed over several centuries, has traditionally fallen within the domain of plant taxonomy in an academic setting: universities, research museums, and botanical gardens. The question that needs to be asked is not only to what extent this legacy is being maintained, but to what extent the components are currently available to whomever is actually doing the bulk of analyzing and describing regional novelties, whatever their professional credentials and self-identities might be.

A prime example is the situation referred to above, in which large universities that house major herbaria struggle to justify their upkeep while simultaneously relegating descriptive systematics to less well-equipped or well-situated institutions. The transfer of floristic survey work to the domain of ecologists, another apparent trend, is also a potential problem if it is not accompanied by the transfer of associated skills and techniques (e.g., critical taxonomic analysis and an understanding of the role played by vouchers). Paradoxically, it is possible that, in the name of increasing the scientific respectability of systematics, one outcome might actually be a net *decrease* in the scientific standards underlying the analysis and description of new species, the very foundation of our knowledge of biodiversity.

ASSUMPTION 4: THE PROPERTY RIGHTS CONFLICT

A. SOCIOLOGICAL RAMIFICATIONS OF FLORISTIC SURPRISES

Furthermore, what are the broader ramifications of allowing taxonomy and floristics to take place largely as a collective avocation, a labor of love even for those in professional positions, rather than an academically supported undertaking? For better or worse, the days when new taxonomic and floristic discoveries were of concern only to professional botanists and amateur enthusiasts are far behind us. Although there are numerous exceptions (e.g., *Juncus tiehmii* Ertter, which is widespread in western North America), the majority of newly described species qualify for some level of sensitive species status, with immediate implications for land-management activities on public and private lands. Problems can arise if negatively affected landowners develop the impression that so-called "amateurs" are behind newly described rare species without the backing of socially sanctioned expertise.

Even for those species that aren't novelties, a lack of sufficient information on their taxonomy and distribution interferes with effective conservation efforts. The magnitude of this problem can be seen in the list generated by Skinner et al. (1995) of 182 rare California plants for which further taxonomic resolution is needed, and another 44 that require additional distributional information before their conservation status can be properly assessed. The implications of this knowledge gap become apparent in the face of decisions that are being made now which will irrevocably determine the fate of much of our natural heritage, representing a vast resource containing both pragmatic and aesthetic values.

B. IN FRONT OF THE BULLDOZER

In this context, it is unsettling to realize how many plants (and other organisms) that would qualify for some level of management activity, possibly representing 5% of the North American flora (based on Taylor's extrapolations as previously discussed) and including some of the rarest of the rare, are currently receiving NO attention because they have not yet been discovered, analyzed, and described. In other words, we risk losing a significant percentage of our floristic heritage out of sheer ignorance of its existence, not just in the tropics but in our own backyards.

In support of this statement, an increasing number of novelties in North America, as in other parts of the world, are being discovered "in front of the bulldozer." The type locality of *Neviusia cliftonii*, for example, is threatened by a limestone quarry, and the monotypic genus *Yermo* was discovered as part of a survey along a proposed pipeline route. The narrow endemic *Ivesia aperta* (J. T. Howell) Munz var. *canina* Ertter (Rosaceae) was still in manuscript when plans to build a dam that would have flooded almost the entire population came to light (Ertter, 1988). *Ceanothus ophiochilus* S. Boyd, T. S. Ross & L. Arnseth (Rhamnaceae) was found during the environmental impact study of a proposed development in southern California (Boyd et al., 1991). Even more recently, the type population of an undescribed *Pseudostellaria* (R. Hartman & R. Rabeler, in. prep.) was found adjacent to the staging area for an active logging site, potentially surveyed for sensitive species prior to approval for timber harvest, but not for undescribed taxa. A new tarweed currently being described from Livermore, California, also falls into this category, occurring as it does in an area of some of the heaviest development pressure in the San Francisco Bay Area (Baldwin, 1999).

Unfortunately, there is also evidence of potential novelties being eliminated before they could even be described. This may be the case with an undescribed *Eriogonum* mentioned in the protologue of *E. capistratum* Reveal var. *welshii* Reveal (Reveal, 1989b), whose only known population in southwestern Idaho has possibly been eliminated by the construction of communication towers.

C. LANDOWNER RESISTANCE TO SURVEYS

In-front-of-the-bulldozer discoveries, exciting as they might be to the botanical community, can be a decidedly rude surprise for the landowner, representing an unexpected and potentially very expensive complication in what might otherwise have been a relatively straight-forward and profitable undertaking. One newspaper covering the rediscovery of the Ventura Marsh milkvetch *(Astragalus pycnostachyus* var. *lanosissimus)* noted how the plant was "causing trouble" and had "thrown a kink" in the developer's plans to build $300,000 homes surrounding a man-made lake *(Sacramento Bee*, 15 Aug. 1997). Fanned by negative publicity and property rights advocates, the fear that property values and development options will be severely curtailed by the discovery of such unwelcome surprises has unfortunately led to a significant polarization between private landowners and advocates of biodiversity protection. This in turn has often resulted in a refusal to allow floristic surveys on private lands, which can contain significant portions of relatively unexplored areas that could harbor novelties and populations of other significant plants.

The scale of the fear and distrust has even led to the paradoxical situation in which local landowners insist that "there are thousands" of a so-called rare plant on their properties, while simultaneously refusing to allow the scientific surveys needed to justify less stringent management options. Frank testimony to exactly this situation, and to the massive amount of distrust, fear, and outrage that can build up in the absence of trustworthy sources of reliable information to the contrary, is provided by Janssen and Williamson (1996). In summarizing her efforts to gain access to reported populations of *Frankenia johnstonii* Correll (Frankeniaceae) on the private ranchlands of Zapata County, Texas, state botanist Gena Janssen (in Janssen & Williamson, 1996: 3) shared these insights:

> "As I began to meet and get to know more and more landowners, I began to notice that most of them did basically the same thing when they met me: They yelled at me. And then one day it finally hit me as to why they did that. Finally, they had a person, a warm body, in front of them that represented all these endangered species issues that had been scaring them for so long. They just needed to vent, so I let them. They had no one there for them. There was no one there to say, 'No, that's not true,' or 'Yes, that was a very difficult situation for everyone,' or 'Well, only part of that is true,' etc., until now."

Encouragingly, this stage was the prelude to a particularly noteworthy success story. Janssen's patience, honesty, and willingness to listen compassionately paid off, first in obtaining the access needed to acquire critical distributional and other biological data on a plant that occurs almost exclusively on private land, and subsequently in working with the landowners to develop a voluntary conservation plan. As a result, *F. johnstonii* is currently being removed from the endangered species list, with many of the ranchers now taking legitimate pride in "their" rare plant (Janssen, pers. comm. 1998; see also http://www.tpwd.state.tx.us/news/news/980518a.htm).

In this context, there is a distinct irony in the fact that the fundamental floristic work in Kern County, California, currently a property-rights stronghold, was undertaken by a local rancher, Ernest C. Twisselmann. His contributions to California botany have recently been acknowledged in the form of a newly discovered genus named in his honor, *Twisselmannia* (Al-Shehbaz, 1999). Twisselmann's interest in botany, triggered by an outbreak of nitrate poisoning in his cattle (McClintock, 1973), eventually led to the publication of two floras (Twisselmann, 1956, 1967) and the discovery of several new species (e.g., *Nemacladus twisselmannii* J. T. Howell, *Eriogonum temblorense* J. T. Howell & Twisselm.). The acknowledgments to his 1967 flora provide insight into the respect for private property that lay behind the success of his undertaking.

> "In a time when malicious trespass and vandalism are almost an acceptable form of outdoor recreation, locked gates are essential and a suspicion of even well-intentioned strangers is a natural attitude of rural people. So I am doubly grateful for the open-handed trust and generosity of the many landowners who freely gave me access to their property, and whose friend-

ships have been one of the quite unexpected dividends of the fieldwork."

D. FLORISTIC SURPRISES OR "NO SURPRISES"?

The *Frankenia johnstonii* example is only one among many in which an increased floristic information base, sometimes paid for by the private stakeholders, worked in their favor, either by providing sufficient scientific evidence for reduced protection status (e.g., downlisting) or by increasing the mitigation options. These examples need to be brought together for impact, but currently exist only in scattered documents and word-of-mouth reports. Granted, there is a difference between a ranch family that wishes to continue a way of life requiring large open spaces, and a developer who needs to subdivide and build in order to realize an investment. Even in the latter case, however, the negative consequences of floristic ignorance can cut both ways, increasing the risk of misplaced mitigation efforts as well as the unintentional extinction of species.

As a society, we have acknowledged that the perpetuation of our biodiversity heritage is a highly desirable goal, for pragmatic, aesthetic, and ethical reasons. Within this context, the key question becomes how to accomplish this goal as fairly and effectively as possible. Unfortunately, instead of making the necessary hard decisions on a solid basis of complete scientific knowledge of all elements involved, we are forced to face the tragic fact that the "best available scientific evidence" is often a woefully inadequate reflection of the actual data needed for the kind of far-reaching decisions that are currently mandated.

A common quandary, for example, is determining whether a species is truly as rare as existing evidence indicates. In these circumstances, it is sometimes argued that, if the scientific evidence is incomplete, then no land-management constraints can be justified. This argument, however, runs counter to the fact that all legal decisions, including those addressing environmental issues, are based solely on best evidence available at the time of the decision, with neither hearsay nor supposition having a legitimate role. One can speculate that a species is more widespread than the currently available scientific evidence indicates, but a decision based on this speculation without hard evidence to back it up is no more justified than is ruling on a defendant's guilt strictly on speculation that the person *might* have done the crime. Given this, it is readily apparent that operating from a maximally comprehensive and accurate information base is vastly preferable to acting in ignorance, and willful ignorance becomes inexcusable, if not outright foolish. When all is said and done, the best guarantee of "No Surprises" (the nickname for a key landowner incentive in regional conservation plans) is complete information up front.

ASSUMPTION 5: THE OVERWHELMING CHALLENGE

Within this framework, the significantly preferable option to isolated, development-driven surveys would be a proactive, comprehensive effort to address the existing gaps in our floristic information base. It works to no one's benefit for an undescribed plant or a significant population of a sensitive species to be discovered *after* significant funds have already been expended on a proposed project [e.g., a newly discovered *Draba* that is "complicating Olympics preparations" for the 2002 Winter Games in Utah, having been found at the site of the men's downhill race course (*Deseret News*, 22 Aug. 1998; Windham & Bellstein, 1998b)]. There is furthermore a distinct sense of unfairness in having the short straw fall to the landowner(s) of the last refuge of a once-common species, which only became endangered when neighboring landowners had developed their parcels first.

Avoiding such situations is in fact a primary goal behind the current focus on developing regional conservation plans on which to base land-management decisions. Although excellent in principle, in reality such efforts have often been deficient in addressing species-specific information, in large part because of the assumption that obtaining the relevant species-specific floristic information is too formidable a challenge to pursue. This in turn leads to the argument that alternate information (e.g., satellite imagery, umbrella species) serves as an adequate substitute to field-based, species-specific floristic data. A dramatic counter to this argument is provided by the Shasta snow-wreath (*Neviusia cliftonii*), in which a relatively conspicuous shrub was completely overlooked by one of the most complete vegetation mapping projects ever undertaken (Weislander et al., 1939). As a bottom line, large-scale land-management plans that address only dominant and formally listed species have the potential of allowing the incremental disappearance of all other species in the region, including any undescribed novelties, without even leaving a record of their previous existence.

The challenge of comprehensively addressing the species-specific gaps in the floristic information base is indeed formidable, but the assumption that it is an overwhelmingly unrealistic goal is based in large part on the assumptions previously addressed.

In particular, it can hardly be said that the assumption has ever been put to the test, given the low level of support that floristic efforts have historically received. For such an undertaking to become a reality, however, the following would accordingly need to be addressed:

- acknowledge incompleteness of existing floristic knowledge base;
- assign value to floristic information commensurate with the effort required to generate it and its value to society at large;
- ensure that essential academic resources are available at regional level;
- foster the network of professional and para-professional expertise;
- promote the training and participation of para-professionals within a framework of acceptable scientific standards;
- depolarize relations with private landowners, with academic participation providing an essential agenda-neutral framework;
- disperse floristic information in a framework that addresses the particular needs of all participants.

Several possible prototypes incorporating one or more of these elements have already been developed. The Rocky Mountain Flora Project, for example, demonstrates the scale that can be accomplished by focused floristic surveys within an academic setting (Hartman, 1993). In contrast, the Oregon Flora Project depends less on graduate student projects and more on existing and newly generated information from an extensive network of academic, agency, and native plant society sources, critically analyzed by herbarium-based professional systematists (Sundberg, 1997). The 1980 peak of novelty description in Utah, as shown in Figure 1, resulted in large part from the collaborative activities of regional academics, agency biologists, and environmental consultants, and similarly collaborative "haybaling expeditions" have taken place in Idaho (Big Horn Crags) and the southern Sierra Nevada. In the San Francisco Bay area, a regional checklist was specifically designed to facilitate and encourage the participation of para-academics in floristic inventory efforts (Ertter, 1997b). In that all of these efforts, and the discovery of "floristic surprises" in general, have proceeded with minimal institutional support in an increasingly avocational network, one can only speculate as to what could potentially be accomplished within the framework of a well-coordinated, seriously supported floristic undertaking, taking full advantage of both professional and para-academic networks.

The Big Picture

In conclusion, I propose that what taxonomists have been up to is nothing less than one of the most massive scientific endeavors ever undertaken: namely, a centuries-long, internationally collaborative effort to model global biodiversity. If this does not qualify as "Big Science," I don't know what does! The significance of this undertaking takes multiple forms, starting with the fundamental desire to know what other forms of life share this planet with us, the only island of life we know for certain exists in the universe. The resultant model also forms the foundation underlying other branches of biological knowledge, and it follows that the more complete and accurate the model is, the stronger the foundation is (cf. the "taxonomic impediment" of R. W. Taylor, 1983). Most important, as we now find ourselves in an era when crucial decisions are being made that will determine the face of life on the planet, it is imperative that these decisions be made with the most comprehensive information possible.

Furthermore, the challenge of obtaining the species-specific floristic information needed to make science-based land-management decisions in North America north of Mexico, although formidable, is not beyond our grasp. However, the viability of the essential professional taxonomic infrastructure needs to be ensured, and the undertaking approached as a seriously supported collaborative effort combining academic and para-academic resources at the regional level. If not, then we risk losing 5% of the floristic diversity in the North American "backyard" by ignorance alone, as well as unfairly allocating the conservation costs for biodiversity in general.

A quote by Thomas Bridges opened this paper, expressing his amazement that there were still floristic surprises in North America in 1858. I will end with a more accurate perception by Dieter Wilken, expressing his delight in the Colorado flora in 1984, over a century after Bridges' visit to California (transmitted by R. Patterson, pers. comm. 1998): "I am continually amazed at the things that are yet to be discovered."

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